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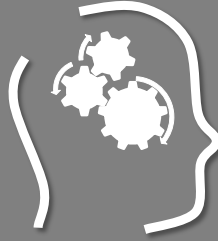
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BIM Anatomy

An investigation into implementation prerequisites



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On Beginning:



"Whatever you can do, or dream you can, begin it. Boldness has genius, magic, and power in it. Begin it now." (Goethe)²

¹ All portrait images sourced from Google images, www.google.com

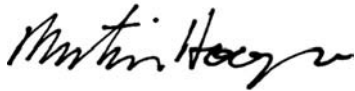
Dedication

To my wife and new young family.

² Johann Wolfgang von Goethe German dramatist, novelist, poet, & scientist (1749 - 1832)

Preface

This work represents a Licentiate Thesis and is based on research carried out at the Division of Design Methodology, Department of Construction Sciences, Faculty of Engineering, Lund University, between 2010 and 2012. It has in many respects been a voyage of personal and professional discovery. It is a result of many things. It is first the result of ten years of observation of IT-based working in architectural practice and seeing how much we do it the wrong way. Not that there is necessarily any one right way. But to see design technology introduced in a way that undermines practice resources, compromises co-ordination of output and contributes to delay and over expenditure on construction projects has been a sobering experience. The result of this observation is a belief that there must be a better way. A better way to both use people's talents and to do so in such a fashion that we all get a taste of result, feel a part of a team conspiring to do their best, and that we can make a difference in execution.

A handwritten signature in black ink, reading "Martin Hooper". The signature is written in a cursive, flowing style with a prominent flourish at the end.

Martin Hooper

Lund, 2012

Acknowledgements

I thank Architect, Professor Anders Ekholm for his concise and wise guidance throughout the project and for being flexible from the start.

I would like to thank consultant and construction organisations White, Tyréns, Fojab, Skanska & NCC for their contribution and the opportunity to collaborate with willing and innovative industry participants in the field. The author would also like to thank all those whom have taken their time to be interviewed or questioned in the course of the data collection associated with this study. A particular thanks to Gunilla Qvarnström, Ole Dellson, Pål Hansson, Jens Kindt & Mårten Fridberg amongst others, who have helped in accessing the right information, provided key feedback and a platform to test improvement proposals in practice in parallel with live construction projects. It has been a delight to see the interest in a number of concepts developed by the project in both teaching and practice. I believe that an activation of practice-research will become a decisive factor for the development of BIM implementation and I look forward to the future.

In addition I would like to acknowledge Ronny Andersson for his insightful comments and helpful steering.

Finally, I would like to express my thanks to my wife Pia for being there, for being supportive, for putting things on hold, for being interested, bemused and amused as well as little Max for being alive and patient with Daddy.

This research project is funded by SBUF, Formas-BIC, Interreg IV and members of OpenBIM.

Abstract

This thesis presents the results of an investigation into BIM implementation prerequisites emerging as a set of procedural supporting mechanisms that may enable design, construction and operating (DCO) organisations to advance their deployment of Building Information Modelling (BIM) technology, and improve construction project outcomes.

Today, BIM is centre-stage within the construction sector the world-over. It is seen as a means to overcome those age-old difficulties in communications and information management that have plagued the industry for centuries. Where other industries have succeeded in leveraging significant benefits from IT solutions, the construction industry has struggled to achieve similar productivity gains for practical and methodological reasons.

The utilisation of BIM has become a strategic area of development that may enable organisations to create new business opportunities and more efficient methods of creating, coordinating and sharing facility information through design, construction and operating phases.

Whilst BIM has shown promise elsewhere, in Sweden difficulties in moving forward are arising in part as a result of a lack of national guidelines and consistent approach. Here it is conjectured that development in prerequisite standards, information delivery specifications and collaboration support may offer the conditions necessary for success.

This work aims to develop methods and processes that support organisations in their use of BIM technologies with the purpose of solving collaboration issues and information exchange obstacles. It is focused primarily on requirements through design phases with close cognisance to the downstream use of construction data.

A number of case projects are employed together with industry interviews and workshops to enable theories to be tested that focus on information exchange requirements and unravelling collaboration hindrances. The research method entailed working directly with practitioners to identify and analyse barriers to the routine use of BIM in practice. The underlying hypothesis is that methodical deployment of BIM can provide answers to a myriad of organisational and information management problems affecting the industry today provided the appropriate mechanisms exist to support users. The thesis reports on the necessary standards, information deliveries and the collaboration processed necessary for successful BIM implementation through a rigorous piece of research, integrated case studies, experiments and observations over an intense period of investigation.

Based on case materials, theory and literature review, a comprehensive set of process-based BIM procedures emerge as a system of support measures that can be deployed on a project basis. Intended to draw teams together to do the best for the project, the support

mechanisms may enable teams to leverage their expertise, tools, and the data they create more effectively thus adding value to the project.

Standardisation of BIM working practices, processes and methodologies can be seen as a key issue for the industry, not least for those involved in the early stages when BIM information authoring is at its most intense. With so many processes and people involved over time from concept to maintenance, to reach a steady-state of information order may be impossible. However what is possible is to ensure a number of key procedures are in place to both optimise organisation and stewardship of information that is critical throughout a facilities life cycle.

Keywords: BIM, Building Information Modelling, strategic planning, information exchange, collaboration.

Svensk Sammanfattning

Denna avhandling presenterar resultat från en undersökning av förutsättningarna för införandet av BIM i form av ett antal processtödande mekanismer som möjliggör för projekterings- och byggorganisationer att främja tillämpningarna av BIM tekniken och förbättra byggprojektens resultat.

Idag är BIM i centrum för byggsektorn världen över. Det ses som ett sätt att övervinna de urgamla svårigheter i kommunikation och informationshantering som har plågat branschen i århundraden. Där andra branscher har lyckats dra nytta av betydande fördelar med IT-lösningar, har byggbranschen kämpat för att uppnå liknande produktivitetsvinster av praktiska och metodologiska skäl.

Användningen av BIM har blivit ett strategiskt utvecklingsområde som kan möjliggöra för företag att skapa nya affärsmöjligheter och effektivare metoder att skapa, samordna och dela bygginformation genom projekterings-, bygg- och förvaltningsprocesserna.

Även om BIM har visat lovande resultat på andra håll, uppstår svårigheter i Sverige att gå vidare som en följd av brist på dels nationella riktlinjer, dels en konsekvent strategi. Här förslås att utvecklingen av standarder, leveransspecifikationer och samverkansstöd kan erbjuda de nödvändiga förutsättningarna för framgång.

Detta arbete syftar till att utveckla metoder och processer som stödjer organisationer i deras användning av BIM teknik med syfte att lösa samarbetsproblem och hinder vid informationsutbyte. Arbetet är i huvudsak inriktat på krav i projekteringen med nära beaktande av den fortsatta användningen i byggproduktionen.

Ett antal fallstudier har använts tillsammans med industriintervjuer och workshops för att testa teorier som fokuserar på krav för informationsutbyte och påvisande av samarbetshinder. Forskningsmetoden innebar att arbeta i direkt samverkan med praktiker för att identifiera och analysera hinder för rutinmässig användning av BIM. Den underliggande hypotesen är att ett metodiskt införande av BIM kan hantera den myriad av organisatoriska och informationshanteringsmässiga problem som påverkar branschen i dag, under förutsättning att lämpliga mekanismer finns för att stödja användarna. Avhandlingen visar på de nödvändiga standarder, informationsleveranser och samarbetsprocesser som krävs för ett lyckat genomförande av BIM genom en rigoröst genomförd forskningsprocess innefattande integrerade fallstudier, experiment och observationer under en intensiv undersökningsperiod.

Baserat på fallstudiematerial och teori- och litteraturgenomgång, utvecklas en omfattande uppsättning processorienterade BIM metoder som ett system av stödande åtgärder för tillämpning i byggprojekt. Åtgärderna samlar projektmedlemmarna kring projektets bästa

och kan hjälpa dem att utnyttja sin kompetens, sina verktyg och de data som skapas för att på ett mer effektivt sätt höja projektets värde.

Standardisering av BIM-tillämpningar, processer och metoder, kan ses som en nyckelfråga för branschen, inte minst för dem som deltar i de tidiga skedena när skapandet av BIM-information är som mest intensivt. Med så många processer och människor engagerade från idé till förvaltning, kan det vara omöjligt att uppnå ett stabilt tillstånd av koordinerad information. Men det som är möjligt är att säkerställa att ett antal viktiga förfaranden är på plats för att både optimera organisationen och hanteringen av information som är viktig under hela byggnadsverkets livscykel.

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Abbreviations

Acronym	Description
AEC	Architecture, Engineering and Construction (Industry sector)
AIA	American Institute of Architects
AMA	Common Material & Work Specification
BIM	Building Information Modelling
BSAB	Swedish Construction Classification System
buildingSMART	Industry body responsible for developing IFC's, IFD, IDM, MVD's
CI/SfB	Construction Industry Classification System
CITS	Centrum för Informationsteknik i Samhällsbyggnad
COBie	Construction Operations Building Information Exchange
DCO	Design - Construct - Operate (Industry process)
FGI	Focus Group Interview
FM	Facilities Management
ICT	Information and Communication Technology
IFC	Industry Foundation Classes (Data structures for representing information used in BIM)
IFD	International Framework for Dictionaries
IDM	Information Delivery Manual
IPD	Integrated Project Delivery
MVD	Model View Definition
OCCS	OmniClass Construction Classification System
STEP	Standard for Exchange of Product Model Data
XML	Extensible Mark-up Language

The Author

Hooper is building a system of best practice scenarios for successful BIM Implementation, turning Sweden into a nation of efficient building information managers in the process. He doesn't care much for today's focus on innovation and development, because far too much starts and ends as ideas on whiteboards. Welcome to the man who can handle a shredder and make blueprints for a better BIM world, with dedication enough to implement a big idea over a long period of time.

Hooper could have chosen to spend his life and his aptitude at a cosy studio earning respectable architect wages. However, he chose to spend a number of formative years in the Nordic academic world in order to realize an idea that in its initial phase seemed insurmountable. An idea that doesn't promise personal profit and that carries no small risk of failure.

The Man

Hooper trained as an Architect at the School of Architecture, University of Strathclyde, majoring with 1st class honours. Besides having participated in numerous experimental and real world design and construction projects throughout the UK and Nordics, he is one of the first British architects in Sweden to have been awarded the designation 'Certified European Passive House Consultant'. Driven by thoroughness and meticulous attention to detail his mission in life has always been to walk the extra mile.

The Dream

What is interesting for me is to look into and attempt to solve matters of consequence that have been irksome to me (and a whole load of others) for years and that there just has not been time for, before on to the next project. It's a matter of finding the solution, controlling data properly and been able to be on top of the project instead of allowing information anarchy to prevail.

For Hooper part of the joy of creating is the bringing together of parts (components that may in some cases already be readily available) and make something that's not available elsewhere. Going somewhere entirely new and rough where alternatives can be eked out.

On dedication to science & progress:



"Difficulties mastered are opportunities won". (Churchill)³

³ Winston Churchill: British Orator, Author and Prime Minister during World War II. (1874-1965)

A Guide to this thesis

Target Audience

Whilst this thesis walks a tight line between scientific research and consultant research, it is first and foremost written as an academic assignment for the degree of licentiate of engineering. The work is designed to offer a contribution to the furthering of the construction industry and, since the particular subject matters affects virtually the whole spectrum of disciplines and support disciplines, it is hoped and anticipated that this thesis will be of interest to a broad range of sector participants: practitioners and academics alike. Individuals engaged or observing in all stages of construction projects: clients, designers, estimators, purchasers, contractors and facility managers, it is hoped, will find the material and findings interesting and of practical inspiration for further development in the area.

An awareness of BIM and its potential benefits to the industry sector wide is already well established, but a text providing further insight into resolving implementation matters and planning the execution of BIM processes may catch the interest of those struggling either to leverage value or educate students in best practice. This thesis attempts to draw at least the curiosity of all those concerned with DCO information management and process improvement.

Thesis Structure

This document consists of 3 parts. The first part comprising the main cover composition divided in to 7 Chapters, the second being 3 appended papers and the third being 2 appended documents.

Part 1: The Cover

Chapter 1: *Introduction* – introduces the reader to the research field, outlines the aims and purpose and identifies the research questions.

Chapter 2: *Methodology* – presents the chosen methodology for the research and the different methods for collecting, organising and analysing empirical data supporting the various studies and findings.

Chapter 3: *Theory* – a background on which this research aims to build, this section presents amongst other things, a variety of existing BIM Implementation protocols in a search for identifying the key prerequisites for success in a Swedish context.

Chapter 4: Findings – presents the empirical findings collected through the course of the research project. Representing both qualitative and quantitative data, a number of graphics attempts to present the findings in an enlightening context.

Chapter 5: Conclusions - reconnects the aim of the study to the findings and suggests key industry changes based on the results deduced from the research papers.

Chapter 6: Discussions - here discussions of the findings is presented, mapping findings to system design and tuning requirements to sector needs, concluding with suggested recommendations for further research in the field of construction information management and strategic BIM Implementation.

Part 2: The Papers

The second part comprises 3 appended papers. The first two incorporating results from case projects and the third paper investigates contractual hindrances to teams engaging in collaboration routines essential to leveraging the full benefits of BIM. The final part contains 2 appended supporting documents. The full papers are appended at the end of the thesis.

Paper #1:

- ✦ Hooper, M., Ekholm, A., (2010) A Pilot Project - Toward BIM Integration - An Analysis of Design Information Exchange & Coordination, *Proceedings of the 27th Annual CIB W78 International Conference - Applications of IT in the AEC Industry*, Cairo, Egypt. 15-17 November 2010.

Paper #1 investigates and attempts to define the functional requirements for integrated information management through the design stages of a construction project in Sweden. In a pilot study concerning a residential project the buildingSMART Alliance's new Building Information Modelling Execution Planning Guide provided a framework for the study. The principle BIM planning procedures are applied to the case, tuning requirements to the specific project and localised to support Swedish classification standards. Through the enquiries required to develop and define these processes, a new information exchange protocol emerges, tuned to the Swedish residential sector.

Paper #2:

- ✦ Hooper, M., Ekholm, A., (2011) A BIM Delivery Protocol, *Australasian Journal of Construction Economics and Building, Special Issue on BIM*, Sydney, Australia.

Paper #2 seeks to explore and define content of model information deliverables for a number of key primary specific BIM uses such as 3d Design Coordination and early Energy

Appraisal through an analysis of practical application. It may prove possible to generate machine-readable model information content definitions through the XML schema making it possible to standardise such contents and deliver project information with enhanced certainty.

Paper #3:

- ✦ Hooper, M., Ekholm, A., (2012) *Contractual Hindrances to BIM Collaboration*, LTH, Lund, Sweden.

Unpublished - It is intended that this paper will be submitted to the peer-reviewed journal, for example, *Construction Economics & Management*.

Paper #3 looks at AB 04, ABT 06 together with ABK09 and seeks to identify the key characteristics within these typical contract forms in Sweden which hinder early BIM collaboration. It pulls together the views of a number of industry representatives including architects, engineers, and contractors and considers the impact of key elements of IPD on Swedish working practices.

Part 3: Supporting Documents

2 supporting documents are appended at the end of the thesis. The first is a summary guide initiated through the findings of Paper #1, the second a mini-study reporting on the content, scope and positioning of a number of key existing national BIM guidelines.

Document #1:

- ✦ BIM Implementation – Guidelines for Architects and Engineers

Informed by the findings of research the appended research papers, *BIM Implementation – Guidelines for Architects & Engineers*, aims to address local Swedish AEC industry requirements for a set of consultant guidelines to complement *Bygghandligar 90*⁴ and the *FFi's Digitala Informationsleveranser till Förvaltning*⁵. The model for such a guide is based on

⁴ SI, Swedish Standards Institute (2008), *Bygghandlingar 90 : byggsektorns rekommendationer för redovisning av byggprojekt*. D. 8, Digitala leveranser för bygg och förvaltning, Stockholm : SIS Förlag AB.

⁵ FFi (2011) *Digitala Informationsleveranser till och från Förvaltning – Tillämpningsanvisning: FFi – baserad på Bygghandlingar 90 del 8 utgåva 2*, Version 2011, FFi, Sweden.

the buildingSMART Alliance's new *Building Information Modelling Execution Planning Guide*⁶. Developed to be suitable for use in connection with Swedish construction projects, the new guide suggests a strategic method of BIM implementation through a pedagogical approach to planning and realising an effective collaborating information sharing platform, and aims to fill an organisational gap in existing BIM documentation informed by the insights revealed through pilot studies and scientific rigor.

Document #2:

✦ A Review of BIM-Guidelines: Content, Scope & Positioning

A contribution to the Interreg VI project (activity 3 & 4)⁷, this mini-study aims to firstly catalogue the existing national guidelines and standards applicable to the use of BIM technology around the world and reports on the status of such guidelines with specific focus on those applicable to Sweden and Denmark.

This study reveals significant dislocation between national BIM guidelines and highlights a risk for divergence of standards and BIM working methodology in Sweden. It also has helped identify deficiencies (what is missing) in the context of world best practice documentation in Sweden.

Thesis Outline

The figure below attempts to map out the constituent parts of this thesis and illustrate their relationship to the whole. The content is designed to provide a comprehensive report in response to the research questions and takes the findings towards to their practical application through the appended guideline documents.

⁶ Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2009), *Building Information Modelling Execution Planning Guide*, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

⁷ The Interreg IV Projekt: *Integrering av hållbara Byggprocesser* is an EU funded project which amongst other things looks into the harmonisation of Swedish and Danish BIM Implementation Standards.

BIM Anatomy: An investigation into implementation prerequisites

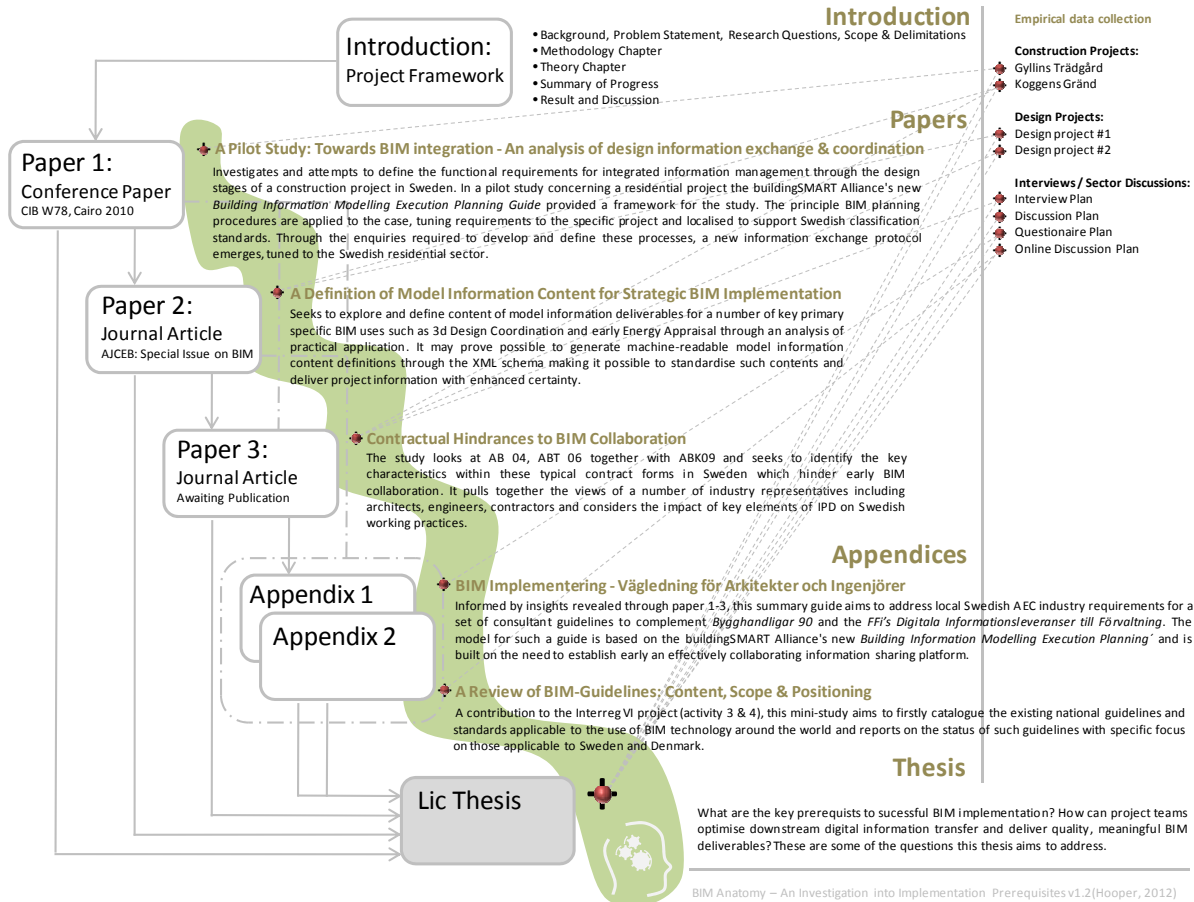


Figure 1: BIM Anatomy – An Investigation into Implementation Prerequisites – Project Plan

On carrying out research:



"In writing a problem down or airing it in conversation we let its essential aspects emerge. And by knowing its character, we remove, if not the problem itself, then it's secondary, aggravating characteristics: confusion, displacement, surprise". (De Botton, 2009)⁸

1.0 Introduction

This chapter provides the background to the research field together with the aims of the research, key definitions and scope. A definition of the problem statement is noted and an outline of the procedure employed to determine the research questions. Notes on literature review, purpose and objectives are included.

1.1 Background to Research Field

There is much business wisdom in working towards developing an industry specific framework to bring the AEC/FM (Architectural Engineering Construction / Facilities Management Industry) in alignment with the constellation of industries that have already benefited from process improvement approaches.

Major clients (like governments and large facility owners and operators) around the world are beginning to insist on the adoption of BIM (Building Information Modelling) and IPD (Integrated Project Delivery) frameworks on public sector contracts as a prerequisite for accepting proposals from designers, builders and other consultants.⁹

In Norway, Denmark and Finland, government mandates are already in place demanding that when requesting services from AEC/FM players, evidence of systemic operational efficiency

⁸ De Botton, A. (2000) *The Consolations of Philosophy*, London: Penguin

⁹ Particularly in the US and to a lesser extent in Australia, BIM capability is an essential prerequisite to public sector work.

is available. Now with major clients in Sweden, under pressure from neighbouring Nordic countries to raise their game, it is highly possible that in the near future, a government mandate demanding AEC operational efficiency in Sweden will materialise. In anticipation of that stipulation, we should start building and optimising BIM implementation routines with some urgency. Judging by benefits reaped by other industries, the rewards of adopting a process improvement framework may be too great to ignore or postpone¹⁰.

We should be surprised that a matter that generally plays such an important part in the success and progress of other similar industries has hitherto been almost entirely neglected by the AEC industry, and to such a large extent lies before us as untreated material¹¹.

OpenBIM¹², a new Swedish industry forum, has recently been established with support from industry organisations whose function is to gather examples of and promote the use of BIM in the Swedish construction sector. Further effort, within the remit of this study is to identify where BIM implementation is appropriate (in terms of scope of project) and how the barriers to up-take can be overcome, with the objective of establishing industry protocols for future ways of working.

The study of BIM working methods and their role in Design, Construct and Operate (DCO)¹³ sector has become a seminal subject of professional as well as academic concern. The research and understanding of the functioning of BIM in practice, the ability of DCO participants to collaborate, to design with certainty and accuracy, and the techniques of manipulating virtual multi-discipline representations to coordinate through digital tectonics has become a burgeoning part of the sector knowledge base as well as one of its hottest research areas.

The figure below indicates a selection of activities where BIM can be deployed through the major project lifecycle phases.

¹⁰ Benefits of successful BIM implementation can be categorised into business benefits and technical benefits. Those who benefit the most are not necessarily those who implement.

¹¹ Whilst it is natural to benchmark the construction industry with other product manufacturing industries such as the auto industry, furniture industry and mobile phone industry where successes have been realised through an enhanced focus on process and product, the nature of the construction industry is quite different not least due to its fragmentation.

¹² www.openBIM.se

¹³ There is no widely used term-definition which is equally representative of all planning-to-demolition *activities* within the construction industry. Whilst acronyms like AEC, AECO, AECOO and AEC/FM refer to the industry itself, the author in concurrence with Succar prefers to adopt DCO as it builds upon the three major project lifecycles and, central to the research matter, provides an accent on key activities: Design - Construction - Operation.

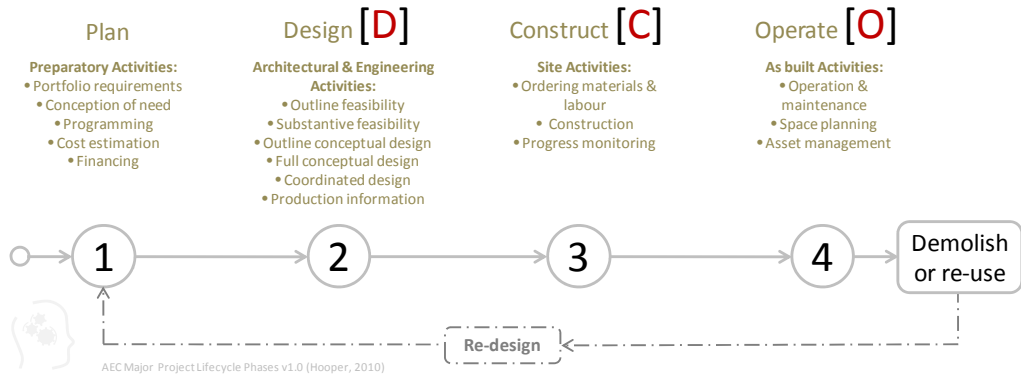


Figure 2: BIM deployment & AEC Major Project Lifecycle Phases

1.2 Problem Statement

Over budget, delays, rework, standing time, material waste, poor communication, conflict - these are typical of the issues facing the construction industry today. With added pressures from the current global economic difficulties, the need to address and resolve these problems has never been greater.

Key to tackling such widespread and internationally recognised woes could be through optimising building design information exchange efficiency and accuracy with a view to creating greater certainty in delivery of construction projects. If implemented intelligently BIM may offer a solution.

Research in the US has shown that rework can be reduced by as much as 30% where BIM is employed.¹⁴ This same report notes a pressing demand for *more clearly defined BIM deliverables between [DCO] parties*.

BIM offers the opportunity to simulate the entire building process virtually before construction and in Sweden, evidence suggests that design coordination errors can be reduced by as much as 50% where 3d object-orientated design models are employed.¹⁵

¹⁴ McGraw Hill Construction (2008), SmartMarket Report: *BIM - Transforming Design and Construction to Achieve Greater Industry Productivity*, New York: McGraw Hill Construction.

¹⁵ Jongeling, R. (2008), *Forskningsrapport: BIM istället för 2D-CAD i byggprojekt - En jämförelse mellan dagens byggprocesser baserade på 2D-CAD och tillämpningar av BIM*, Luleå tekniska universitet, Sweden.

It is clear that construction projects are costing too much and taking too long due to unnecessary omissions and errors in project documentation and sub-optimal co-ordination of design information between consultant disciplines. One reason for this is that traditionally much project production information relies substantially on human input and subsequent multiple manual checks and cross-referencing operations which, on projects laden with design data, inevitably leads to errors or missing information.

Furthermore, construction projects are becoming increasingly complicated in nature, requiring more specialist discipline input resulting in a much greater volume of technical information which in turn requires to be co-ordinated and kept up-to-date and relevant through the life cycle of a project. In such contexts conventional project filing systems and information work-flows are becoming un-manageable. There appears to be a need for clearly defined and agreed information deliveries which if adequately tested, could be standardised.

1.2.1 Difficulties & Barriers to the Adoption of BIM in Sweden

The deployment of BIM in Sweden is not new, however, with the new working methods implied by comprehensive and integrated BIM, a number of difficulties still exist:

- ✦ There is no standard method of implementing BIM in consult practice.
- ✦ Lack of practice guidelines.
- ✦ There is an absence of consensus and understanding of BIM methodology and uses.
- ✦ Difficulties in establishing a collaborative environment with new project teams.
- ✦ Lack of industry contractual provision for BIM implementation and information sharing.
- ✦ Lack of industry entry-level BIM training and existing BIM expertise.
- ✦ Absence of government mandate to motivate all participants to contribute.
- ✦ Difficulties in leveraging benefits proclaimed elsewhere.
- ✦ Lacking interoperability between software applications.
- ✦ Limited ability for design team participants to agree and understand exactly what BIM content to deliver, when, to what level of detail, for which BIM purpose.
- ✦ Many misunderstands or misinterpretations.
- ✦ Lack of reliable information stewardship.
- ✦ Lack of understanding of each other's information needs.
- ✦ Industry resistance to process change.

Successful BIM implementation can only be reached by responding wisely to difficulties that could otherwise lead to disintegration and corporate frustration. Organisations need to accept the pain of the climb but with the right equipment difficulties can be foreseen and effects mitigated proactively.

The diagram below attempts to illustrate an overview of the possible positioning of consultant organisations in the climb over difficulties towards success.

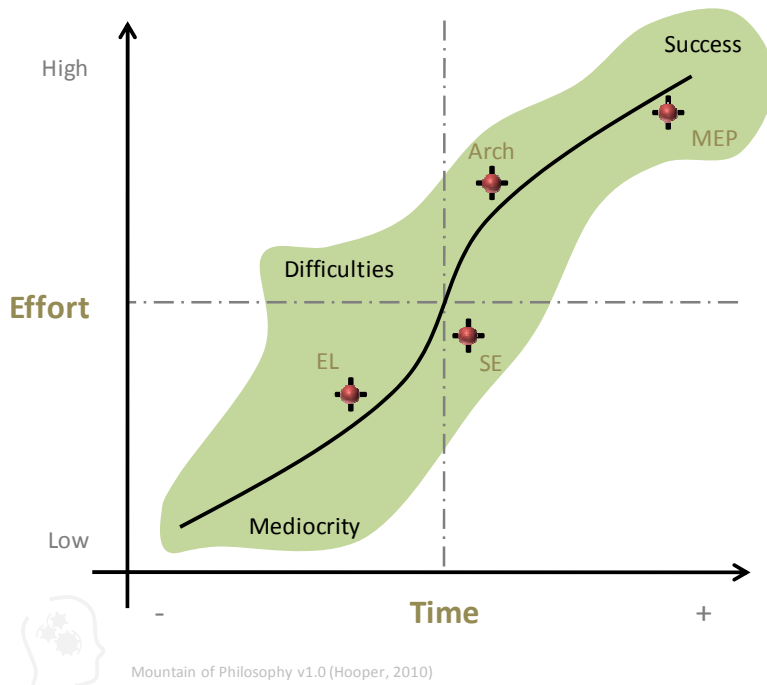


Figure 3: Mountain of Philosophy: Pain of the climb

1.3 Definitions

There are a number of key definitions that are referred to through this thesis which require, for the avoidance of doubt, some clarification. Within the AEC industry there is even dubiety over the definition of BIM itself. For this reason let's start by looking at defining what BIM is all about.

BIM (Building Information Model (As product) & Building Information Modelling (As process): BIM is a 3D modelling technology and design process that has begun to change the way buildings are designed, built and operated. There is no single accepted definition of BIM, however, the following extracts collectively provide an adequate insight:

The Australian National Guidelines for Digital Modelling defines BIM as a model that has two essential characteristics:

- ✦ The first is that it must be a three-dimensional representation of a building (or other facility) based on objects.

- ✦ The second, it must include some information in the model or the properties about the objects beyond the graphical representation (CRC for Construction Innovation, 2009).

Eastman defines BIM as:

- ✦ [...] a modelling technology and associated set of processes to produce, communicate and analyse building models (Eastman et al. 2008).

In the United States, McGraw Hill defines BIM as:

- ✦ The process of creating and using digital models for design, construction and/or operations of *projects* (McGraw Hill Construction, 2008).

Finally, Erabuild defines BIM as:

- ✦ [...] an object-oriented model — a digital representation of a building to facilitate exchange and interoperability of information in digital format (Erabuild, 2008).

The use of BIM has the potential to streamline processes throughout a building’s lifecycle through the integration of design, engineering, construction, maintenance and decommissioning information about a built asset project into a rich data model. The BIM may be a single model or an assembly of models distributed over several separate databases that may interoperably communicate information of common interest. Though a central database is not essential a technical solution can be through the use of a *collaboration hub*.¹⁶

Without too much further explanation, these ideas can be consolidated through the diagram below:

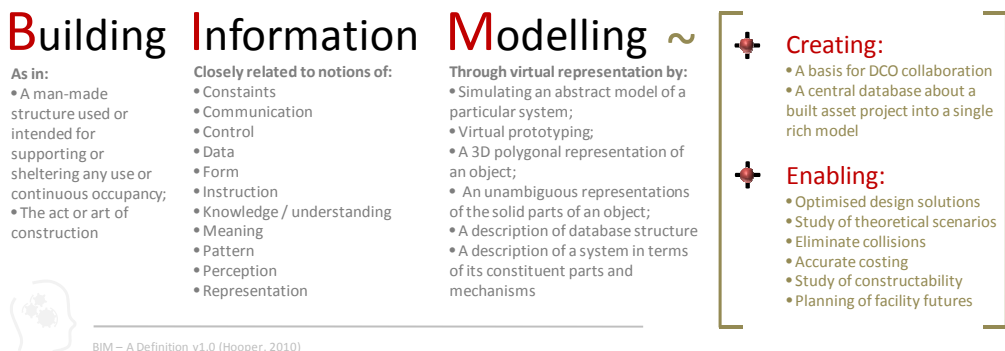


Figure 4: BIM - A Definition

¹⁶ For example: Eurostep’s *BIM Collaboration Hub*, <http://www.eurostep.com>

Collaboration: Collaboration means working together cooperatively, as a team. This assumes that all individuals who collaborate have the same goals in relation to the work that needs to be performed. True collaboration requires all of the team members to have a single understanding of these goals so that their efforts can be supportive and complementary of one another.

Integrated Project Delivery: The delivery of a construction project according to a contract that calls for an integrated design process and that clarifies the legal responsibilities and risks born by all members of the project team.

Integrated Design Process: Active participation in all stages of design for all disciplines involved in the design, construction and, at times, the operation of the building. An integrated design team usually includes an owner's representative; architect; mechanical, electrical and structural engineers; and construction manager and/or general contractor. It can also include future building occupants, facility managers and maintenance staff or sub-contractors.

3-D Parametric Modelling: Model elements not only have the visual aspects of the building aspects they represent but also have the properties of the solids they represent.

4-D Model: Term used to describe the linkage of a time schedule to a model.

5-D Model: Term used to describe the linkage of cost estimating to a model.

Interoperability: The ability of data-rich models to share valuable data, either through import or export.

1.4 The Swedish DCO Sector

Here it is considered suitable to consider and outline a number of significant discrete characteristics unique to the Swedish DCO sector – as distinct to, for example, that of the UK or the US.

Positive Aspects:

- ✦ Sweden has a highly advanced and sophisticated construction industry with high internal investment contributing to multi-faceted optimisation.
- ✦ A number of large construction organisations in Sweden are leading the work with regards innovation and automation in construction.

- ✦ There is a strong appetite from collaboration and co-operation. As distinct from the US for example, Sweden has a positive culture of mutual understanding with little recourse to litigation.
- ✦ A highly regulated state, Sweden has a love for standardisation and values quality.

Failings:

- ✦ The role of the architect is significantly reduced, often with no or limited project management involvement, architects in Sweden are generally employed as design consultants only with little strategic overview found elsewhere.
- ✦ A few large contractor organisations have disproportional power in the construction industry resulting in an imbalanced sector.
- ✦ The Swedish construction industry is stuck in its ways – presenting a strong resistance to change and finding comfort in familiar routines. Once a safe, solid solution is found, there is a tendency to stick to it and dismiss other options.
- ✦ As distinct from its Nordic neighbours, Sweden lacks leadership with cross industry improvement directives – the government has purposely stayed out of the BIM debate and resisted issuing a BIM mandate.

Where BIM can Help

BIM seeks to deliver in the Swedish DCO sector:

- ✦ A better and cheaper built product.
- ✦ Support for both building construction and infrastructure engineering in terms of planning, designing, constructing and operating.
- ✦ Optimised use of technology to automate routine tasks, providing greater opportunity for people to be creative.
- ✦ Improved efficiency in the following areas:
 - i. Downstream stewardship of building information through DCO stages.
 - ii. Design optimisation through an iterative design process and use of simulation tools - enabling strategic design decisions to be based on simulation data rather than guesswork.
 - iii. A more integrated DCO process with collaboration and its core.

1.5 Development of Research Questions

With an outline of the problem area defined, it is now apt to attempt to shape the research questions. First, one may examine the state of existing knowledge to establish if this is adequate to solve these problems or if new knowledge needs to be applied. On the assumption that new knowledge or theories need to come to bear on matter, one can formulate research questions.

Above, we have defined the problem in general terms and can already start to recognise the general line of enquiry. However, to finesse research questions into a form that carry meaning and the potential to contribute to knowledge and science, one should study the existing knowledge with the purpose of defining the gap in that knowledge. Only then can the specific problem and specific research questions be defined. In the process one may discover that there are different problems that each require their own expertise to resolve, in which case one must chose which problems that one is able to solve in the context of one's own background of knowledge and expertise.

In arriving at suitable research questions, questions strong enough and worthy enough to carry adequate meaning and value, it is critical to assemble sufficient intellectual resources to bear on the matter. Robson (2002) in reference to Campbell et al. (1982) suggests the following key characteristics lead to the construction of *good* research questions: involvement, convergence, intuition, theory and value.

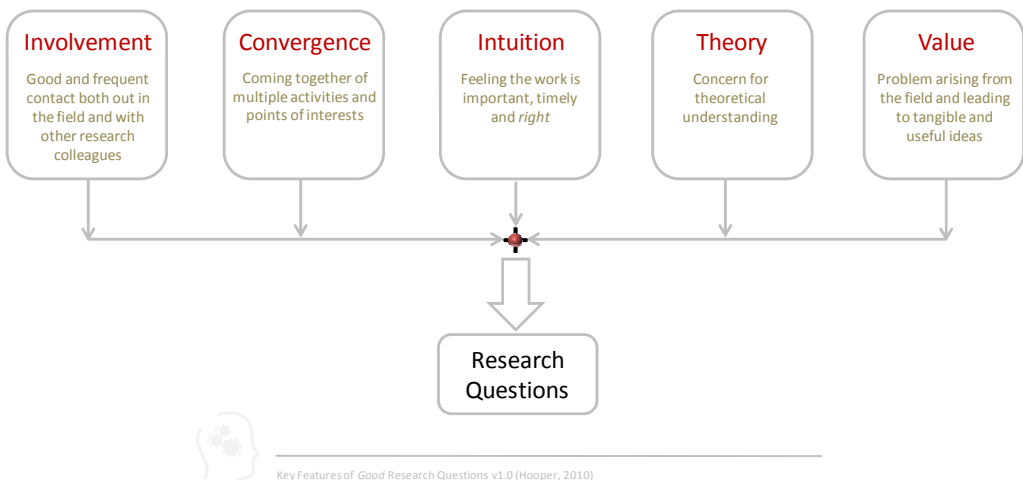


Figure 5: Key Features of *Good* Research Questions (adapted from Robson 2002)

Involvement: Further to the author's decade of experience and engagement in architectural practice, this study involves a number of industry participants who's ongoing feedback and critique helps shape both the direction of the research and reinforce the focus. Frequent

contact with research colleagues both locally and around the world opens doors to matters of consequence and worldly interest offering a variety of alternative perspectives and ultimately richness.

Convergence: Contact and the collection of view points from industry experts and research enthusiasts both nationally and internationally, in academia and from those in practice has enabled a diversity of ideas and viewpoints to be tabled.

Intuition: From both observations, first-hand industry experience, and industry press, the timeliness of research and development in this area is clear. With Sweden trailing behind its Nordic neighbours with regards BIM implementation, a push forward in this area is important for the Swedish DCO sector in its effort to remain competitive.

Theory: The theory behind BIM provides an exciting opportunity to mend some of the longstanding logistical shortcomings affecting the DCO sector today. Reflection on gains achieved within other similar industries suggests that scope for improvement is great.

Value: The key problems to address have arisen from the field and can be considered as real world problems. It is anticipated the results and output from the study will lead to tangible and useful ideas, applicable in practice.

Further to the consideration of these 5 characteristics, the figure below describes a sequence of activities designed to enable a scientific and thorough approach to arriving at suitably robust and appropriate research questions. The process attempts to converge ideas and priorities, and direct the project towards providing real world value.

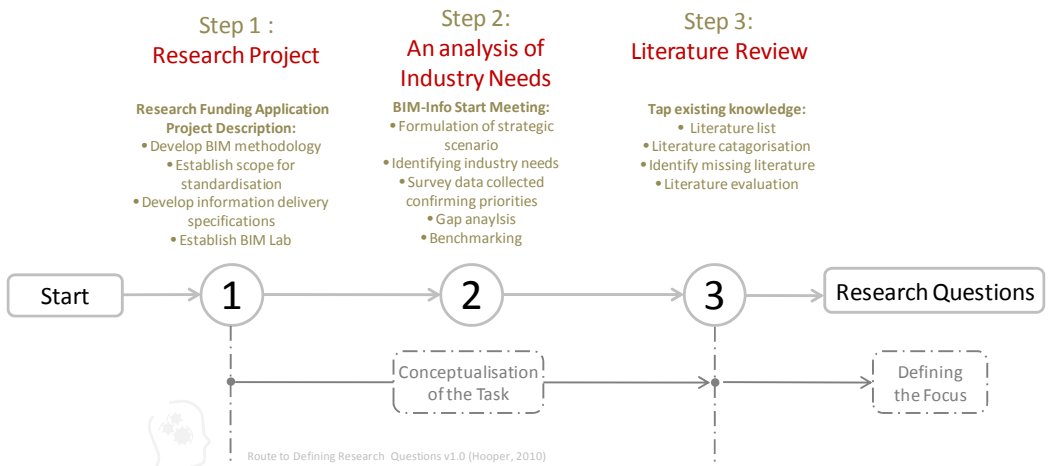


Figure 6: Route to Defining Research Questions

1.5.1 The Research Project

The first step, to extract a duly scholarly interpretation of the research commission (described through the research funding application project description¹⁷) was necessary to ensure a rational comprehension of the task and warrant that funders' expectations are met. The research objectives outlined in the funding application can be summarized as follows:

- ✦ *Investigate requirements for integrated information management in building projects, including:*
 - ✦ *Specifications of objects and properties in information levels at strategic process phases;*
 - ✦ *The role of an information standards coordinating body at sector level;*
- ✦ *Develop methodology and tools for sector cooperation around a university based BIM lab;*
- ✦ *The PhD study concerns requirements for integrated information management as well as advanced use of BIM in building project.*

Furthermore, the call for research applications stated:

- ✦ *The project aims to promote the development of building information modelling in the construction and management processes and make information management more efficient by looking at ways of:*
 - ✦ *standardising information requirements and levels at various stages of construction and management processes;*
 - ✦ *establishing industry-wide guidelines for information coordination,*
 - ✦ *developing and coordinating national and international construction standards for building information modelling, especially framework standard ISO 12006-2, the Swedish BSAB and IFC,*
 - ✦ *establish a university-based lab to support the sector's need to test, evaluate and practicing BIM methodology.*

The PhD research scope includes participation in the development of these areas and independent work to develop knowledge of needs and opportunities within the above areas. Emphasis is put on the national and international standardisation activities in cooperation with its businesses and organisations such as OpenBIM (including Svensk Byggtjänst) and buildingSMART Sweden. The research shall be performed in collaboration with leading players in the construction sector.

¹⁷ Ekholm, A. (2009) Information systematic, BIM lab and pilot implementations – Project Description, PhD Funding Application to SBUF & Formas.

1.5.2 An Analysis of Industry Needs

In order to ensure the research remained focused on addressing real world problems, an industry workshop (BIM-Info Start Meeting) was held at LTH with the purpose, amongst others, of formulating a strategic research focus. Representatives from all corners of the Swedish AEC industry were present to discuss matters of the development of BIM from a number of user perspectives.

The workshop culminated with a summary survey to gather industry thoughts on the BIM-related challenges industry members felt they faced together with where their development aspirations lay. From this material it was possible to establish the essence of industry needs, identify and categorise priorities relating to a desired development of BIM in Sweden and confirm that the work is important, timely and *right*.

Data gathered enabled a summary analysis to be performed that revealed similar concerns. Representatives recommended development was needed in the following areas:

*Definitions for information deliveries, development of national standards, connection to classification system, user perspective, development of exemplar projects as case studies, information exchange standardisation between primary actors, best practice guidelines, AEC collaboration.*¹⁸

By identifying the overlaps between the research project objectives and industry priorities, research questions can further be brought into focus. Here, contact and discussions with practitioners has provided an alternative perspective revealing, at least in part, what is important and what is not.

1.5.3 Literature Review

A further layer of deliberation and reflection was sought through an extensive literature review which enabled sharper, more insightful questions to surface.

With any scientific research it is essential that in the early stages of the study there is a review of the material that already exists on the topic in question. A literature review enables a tuning of relevant and *new* research questions with the purpose of building upon existing knowledge.

¹⁸ These key short statements emerged from the BIM-Info start meeting held on 4 December 2009 following a GAP analysis of participant views on Sweden's DCO BIM development focus.

The literature collected and studied can be categorised as below and was selected from a broad and current range of material relating to BIM development and current BIM implementation issues.

- ✦ Current scientific papers
- ✦ National / International Standards
- ✦ Existing digital modelling guidelines
- ✦ Industry journals
- ✦ Classification systems
- ✦ Text books

The literature reviewed together with online forums and media articles confirmed that the same difficulties exist in other parts of the world where BIM deployment is more advanced, such as the US and Australia, and that the key matters this study hopes to resolve have potentially wide application.

The Mindmap below attempts to chart *how* and *what* literature comes to bear on the research topic. By mapping at least a selection (being the most significant and most relevant, it is not feasible to include everything) of the key literature sources in this way, it enables a vision of the scope of the study whilst simultaneously providing a method of logging insights and illustrating interesting connections which one otherwise may not have considered.

BIM Anatomy: An investigation into implementation prerequisites



BIM Anatomy - Literature Mindmap v1.0 (Hooper, 2012)

Figure 7: Literature Mindmap

The above literature sources come to bear in the following ways:

- ✦ **Current scientific papers:** Because academic articles published in journals generally have their material refereed by experts in the field, the quality of their content can be assured. It is articles like *Understanding and facilitating BIM adoption in the AEC industry*¹⁹ that have enabled a research insight into where the forefront of research in this field lies and even to understand where difficulties exist and a contribution can be made.
- ✦ **National / International Standards:** Here material from standards organisations like Svensk Byggtjänst and buildingSMART are reviewed with a view to establishing what current initiatives are in play in connection with the use of BIM and BIM technology.
- ✦ **Existing digital modelling guidelines:** Early on in the study it was recognised that there is a lack of industry BIM guidelines backed by public initiatives in Sweden. With this in mind, it was important to be familiar with what constitutes a set of guidelines, understand the purpose and the drivers behind them, and identify, with reference to the content, scope, and positioning of other nation's BIM guidelines what may be a prerequisite to successful and mature BIM implementation. A separate mini-study concerning existing BIM guidelines is appended at the end of this thesis.
- ✦ **Industry journals** provide a valuable source of information for the primary reason they present up-to-date news and current affairs – reporting on matters of interest relevant to the industry and the wider society.
- ✦ **Classification systems:** An insight into classification systems and how they might dovetail with BIM is an important aspect of understanding the constituent parts of a working information management system within the construction sector. Here the OmniClass system and its adapted tables represent something of an exemplar.
- ✦ **Text books:** Recent text books relating to BIM provide crucial background knowledge on where we are with BIM and the possibilities of this new technology.
- ✦ **Supporting Guides / Documents:** A review of a number of key existing guides and supporting documents emerging here in Sweden and elsewhere, for example, the AIA's Document E202 offer both an insight into the supporting materials required where BIM is already very advanced (the US) as well as direction and inspiration for what may come to be relevant here if we are to raise our game.
- ✦ **Other Articles,** for example the SmartMarket Reports produced by McGraw-Hill Construction, provide intelligence on market trends, projections, triggers and even where difficulties may lay ahead. Key statistics are available here based on US and world trends.

¹⁹ Gu, N. & London, K. (2010) *Understanding and facilitating BIM adoption in the AEC industry*, Automation in Construction.

Naturally one needs to pay due attention to the authenticity, credibility and representativeness of these sources and evaluate them by considering the source's authoritativeness and trustworthiness. Here, because there are so many sources and documents to be found, it has been reasonably straight forward to identify alternative independent sources to corroborate an impression of the state of knowledge at the forefront of the field.

The reviewed literature gives rise and adds legitimacy to the particular issues, problems and ideas that the current research addresses.

1.5.4 On Literature - A caution:

However, De Botton suggests that rather than illuminating our experiences and goading us on to our own discoveries, literature reviews can come to cast a problematic shadow. They may lead us to dismiss aspects of relevance of which there is no printed testimony. Indeed, far from expanding our horizons, they may unjustly come to mark their limits:

Reluctance to trust one's own, extra-literary, experiences might not be grievous if literature could be relied upon to express all potentialities. But books are silent on too many themes, so that if one allows them to define the boundaries of our curiosity, they may hold back the development of our minds and thwart original contribution (De Botton, 2000).

This philosophical note supports the premise that a literature review, whilst important, in isolation is not sufficient as research question driver. Nevertheless, the importance of literature review lies in *knowing what is known first*.

1.5.5 A Note on the Importance of Networking

Literature reviews, and analysis of practice guidelines have been supplemented by networking both nationally and internationally in various ways. There are naturally a number of existing noteworthy practitioners and researchers who are already doing work linked to the topic of BIM implementation and development. Through both literature searches and networking one can establish what, with whom, and where the *front* of the research is at a particular point and in what way. With this knowledge, an awareness of where we are, one can endeavour to push the front of the particular research field further and make a real contribution to knowledge.

Networking through conferences, meeting and with the use of online tools like Linked-In²⁰ provides useful leads as to what's new in the field and clues as to the questions and challenges currently concerning both industry and academic experts. International groups

²⁰ <http://www.linkedin.com/>

like BuildingSMART, BIMExperts and OpenBIM with online discussion forums are invaluable in today's fast-moving society. Through various means, communication with people who have done or are engaged in work in this research area is important and a key part of responding to real issues and keeping in touch with matters of consequence that are seen as problematic.

1.6 The Research Questions

The definition of the key research questions for this study ultimately centres on an investigation and the development of proposals to enable successful BIM implementation. The above filter stages facilitated a solidification of the research questions specifically designed to consider industry perspectives and address new real world issues.

The research questions build upon the development of 3 key areas which may enable the known difficulties with BIM implementation to be reduced or eliminated.

BIM Implementation Prerequisites

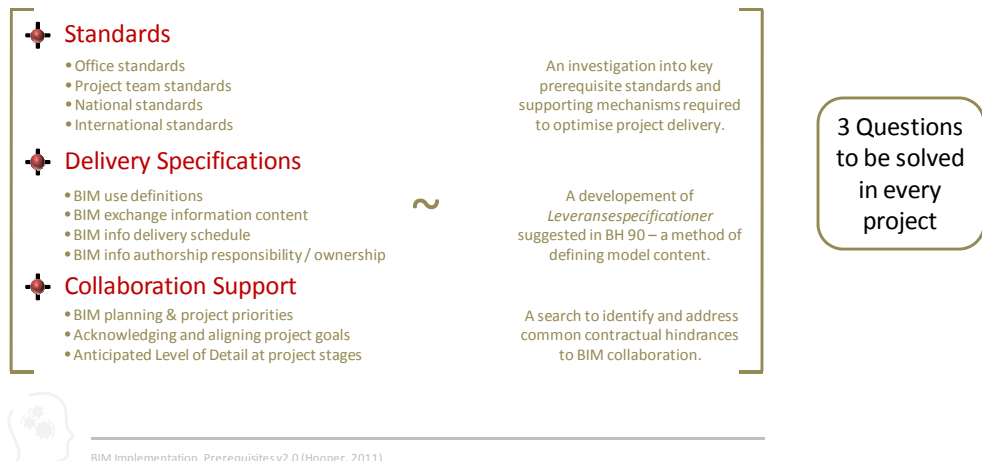


Figure 8: BIM Implementation Prerequisites

From the figure above, the following key questions can be readily extracted:

- ✦ **Standards:** How and in what way do we need to supplement or extend existing standards to facilitate BIM implementation? What are the prerequisite components?
- ✦ **Delivery Specifications:** It is generally accepted that standardising information deliveries for specific BIM uses through the design process is likely to lead to greater efficiency, better coordination and improved certainty. What constitutes a delivery

specification? What are the key information delivery specifications required? What BIM information content is required for each?

- ✦ **Collaboration Support:** Today a myriad of contractual hindrances present obstacles to BIM collaboration. What are these hindrances? Can they be overcome? What is needed to support meaningful BIM collaboration to improve project outcomes?

Resolution to these foundational questions should provide the industry with a platform to deploy BIM on a national basis with the confidence, necessary support and consistency to succeed. This project aims to address the above questions through the following set of research questions and resultant goals:

Research Questions:

The above pre-study, deployed to define the research questions, takes cognisance to a wide range of research sources. Whilst there are a multiplicity of facets to the world of BIM and countless challenges the industry faces in connection with implementation this research focuses on addressing three research questions.

Research Question #1:

What in the way of development / standards / guidelines are needed to support the implementation of BIM in connection with construction projects in Sweden with a specific focus on information exchange and delivery specifications?

This question aims to provide an insight into firstly, what is out there in the way of standards and guidelines, secondly identify what is lacking in Sweden and lastly, to test industry appetite for implementing a pedagogical approach to BIM-Planning to support information exchanges.

Research Question #2:

How could BIM-Info delivery content be articulated in a commonly understood manner on a project basis? Could a standard matrix be established that could be used for various BIM-Uses at various project stages that would help align information delivery expectations?

The second research question (in 2 parts) provides a deeper understanding and a development of the concept of *Leveransspecifikationer* introduced in BH90²¹ but not developed into a working tool.

²¹ SI, Swedish Standards Institute (2008), *Bygghandlingar 90 : byggsektorns rekommendationer för redovisning av byggprojekt*. D. 8, Digitala leveranser för bygg och förvaltning, Stockholm : SIS Förlag AB.

Research Question #3:

How can we reduce or eliminate contractual hindrances to BIM collaboration?

The third research question, not part of the original research project application, revealed itself of paramount importance during the data collection phases in connection with papers #1 and #2 and in tackling research questions 1 and 2. In dealing with implementing project specific BIM-Plans and defining information deliveries for BIM-Uses, a logical next step is to look at what are the difficulties in executing such strategic BIM processes in practice.

Resolution to research question 3 seeks to unlock the difficulties in moving from BIM *organisational optimization* (BIM Level 2) towards BIM *project optimization* (BIM Level 3)²² and address the obstacles to meaningful collaboration on BIM projects (see explanatory diagram below). Overall the answers to the 3 research questions attempt to identify and tie together the prerequisite processes, decisions support mechanisms and documents required for optimised BIM-project delivery.

Whilst some of these matters may be obvious in a traditional design process or design methodology, new processes with new responsibilities are emerging which need to be defined in order to facilitate optimised design co-ordination and integrate BIM into working practices. The broad research question investigated in this study is how the new process requirements may be handled in a systematic way.

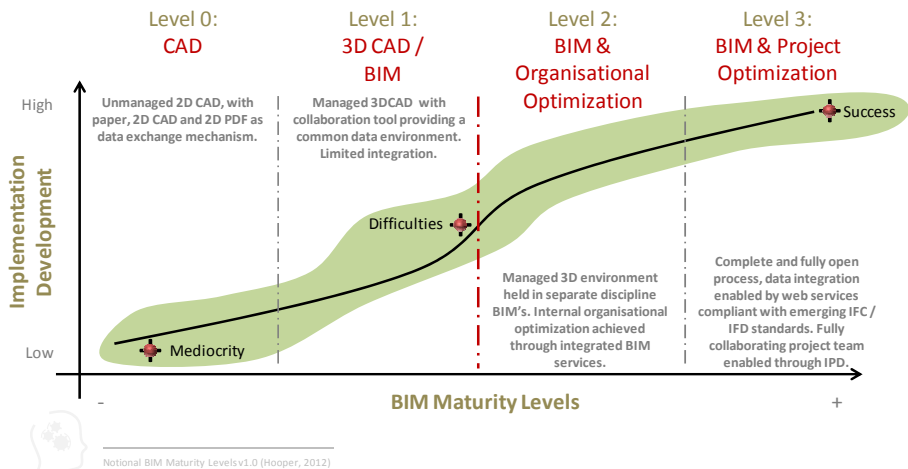


Figure 9: Notional BIM Maturity Levels

²² Notional levels of BIM implementation maturity range from 0-3. See: BIS (2011) *BIM Management for value, cost and carbon improvement: A report for the Government Construction Client Group – Building Information Modelling (BIM) Working Party Strategy Paper*, London. Also implied in: WSP (2011), *Lilla Boken om BIM – Så förändras en bransch*, WSP, Stockholm, Sweden.

1.7 Purpose & Objectives

1.7.1 Purpose

The project's primary purpose is to contribute towards the shaping of the standardisation of the construction industry's production information and administration structure and scope to enable a greater co-operation and collaboration between industry and project participants already possible through BIM but currently hindered due, amongst other things, to a lack of standardised platforms for information sharing.

The work incorporates a study and aims to develop the methods and processes of construction project information and administration systems (specifically BIM) within the industry with the purpose of solving collaboration issues and information transfer obstacles.

The project is orientated towards the specific needs of the industry, and through collaboration with user-groups and existing BIM-user organisations, seeks to support the sector's needs and test, evaluate and develop BIM methodologies.

The work incorporates the developments of methods to:

- ✦ Reveal efficient, trustworthy and robust BIM implementation methods suitable for the Swedish DCO sector.
- ✦ Enable BIM benefits to be realised by DCO participants, not only customers.
- ✦ Make manifest the necessary process changes to achieve BIM integration.
- ✦ Reduce the risk of design information defects through information exchange protocols.
- ✦ Reduce the risk of time and cost overruns.
- ✦ Support and repair the educational sector's lack of university level schooling of architects and engineers in BIM methodology and best practice.

1.7.2 Objectives

The objective of this research project is to render BIM information management more effective through investigating information needs with particular focus on requirements for the Swedish DCO market thereby contributing to the further development of guiding structures supporting BIM implementation.

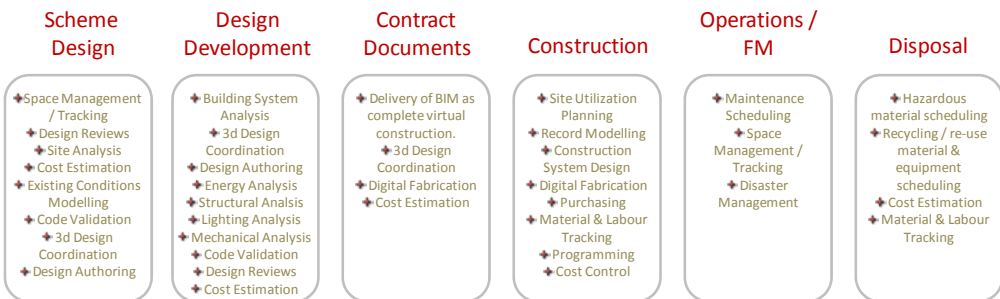
It aims to meet these objectives through firstly; testing the industry's appetite for project-based strategic BIM implementation plans (based on the buildingSMART Alliance's *Building*

*Information Modelling Execution Planning Guide*²³), secondly developing a process model defining BIM information content for specific BIM deliveries, and thirdly identifying and proposing mitigating measures to reduce or eliminate hinders to the necessary collaboration processes that are critical to success.

Furthermore, the project considers how these efforts could be supplemented by coordinating efforts at sector level to avoid problems of sub-optimization and conceptual divergence. Researchers remit also includes testing and disseminating results through teaching at learning at a University based lab.

1.8 Context in the Construction Industry

Already BIM tools are making themselves useful for a whole raft of functions including disaster planning and other technical simulations. Research and development in this field may impinge on every occupation in the AEC sector making the need to resolve strategic and administrative barriers critical to success. The figure below provides an overview of possible applications of BIM through the DCO lifecycle, presenting some indication of context of this research field within the construction industry.



Application of BIM Uses through DCO Lifecycle v1.0 (Hooper, 2010)

Figure 10: Application of BIM-Uses through DCO Lifecycle

²³ Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2009), *Building Information Modelling Execution Planning Guide*, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

Building Information Modelling Execution Planning Guide, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

1.9 Focus and Delimitations

This research project focuses on information delivery through the DCO phases of construction projects within the Swedish construction sector with the aim of moving towards an optimised system of design material delivery and addressing contractual hindrances to collaboration in connection with the use of BIM.

The world of BIM is vast and the problems and difficulties experienced in connection with implementation and leveraging benefits amongst DCO participants equally large. Therefore, in this domain, one needs to be assertively selective when defining the limitations of a study in this field.

The results of this research project are based on empirical data largely collected from case construction projects in Sweden or interview data involving AEC participants operating in Sweden. However the research questions and concluding results are largely applicable to any construction project.

The research focuses on BIM planning and requirements for information sharing largely from a design consultant perspective (as this is where the authors greatest expertise lays) however extends strategic cognisance to the downstream use of such digital information, through the DCO lifecycle (Figure 11).

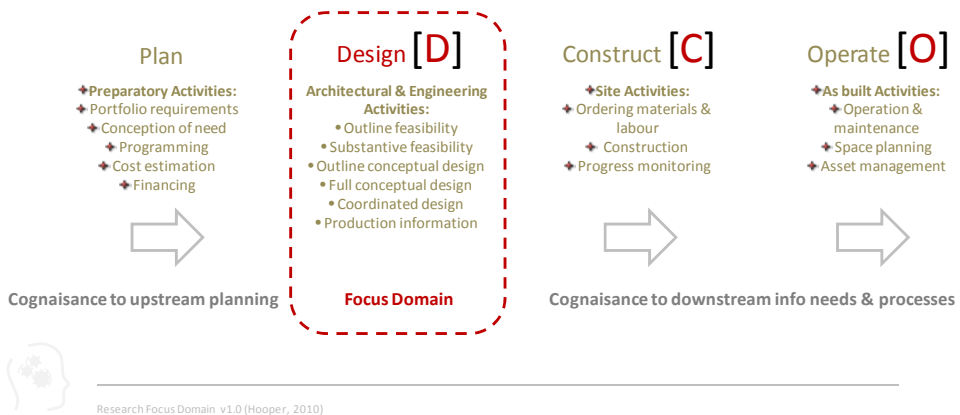


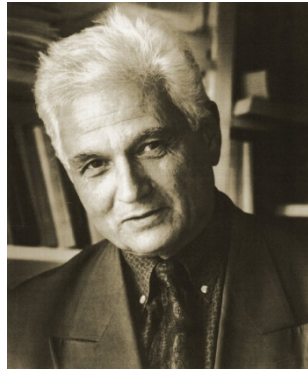
Figure 11: Research focus domain

The cases looked at are construction projects as opposed to infrastructure projects where the ‘push’ and ‘pull’ of BIM demand has different generic characteristics. More is discussed on this later.

Collectively the 3 papers focus on:

- ✦ The suitability of the formulation of a project specific BIM-Plan to support information exchange.
- ✦ A development of BH90's *Leveransspecifikationer* being a method of defining model content for specific uses.
- ✦ Identifying and addressing contractual hindrances to the BIM collaboration, including obstacles to the processes outlined in Paper #1 and Paper #2 from being carried out together with recommendations for other supporting mechanisms.

On methodology:



Every discourse, even a poetic or oracular sentence, carries with it a system of rules for producing analogous things and thus an outline of methodology. (Jacques Derrida)²⁴

2.0 Methodology

This chapter details the methodological decisions made and later implemented in the study. A description of the practical process and the overall design of the research project are presented together with a scientific rationale. It covers the approach - the manner in which the problem (cognitive and practical) is tackled²⁵ and the strategy adopted to collect evidence and extract findings. A particular research design has been developed for this study which is not just social research or technological research, it is both. It concerns people and technology.

First a re-cap on the nature of the research project.

2.1 The Research Project

What is it about?

This study looks into and proposes methods and tools to improve the efficiency and consistency of BIM implementation in the Swedish Design, Construct and Operate fields within the construction sector.

²⁴ Jacques Derrida (1930-2008) French Philosopher

²⁵ Bunge, M. (1999) *Dictionary of Philosophy*, New York: Prometheus.

Why is this research necessary?

To help the industry realise the greater potential that successful adoption of Building Information Management methodologies can manifest in practice and enable early leverage of associated implementation benefits.

Secondly, as an architect I'm interested in industry developments that simply make good business sense.

What is expected to be found?

It is expected to find solutions to address the research questions and ultimately present and communicate a series of both project specific and cross-party functioning measures that enable BIM implementation to be successful.

How is this going to be done?

Through the execution of appropriate research strategies and methods including project case studies, test implementations and experiments. Together with industry workshops and specific collaborations it is projected that this should provide a platform for delivering meaningful results.

2.2 Research Project Workflow

On first consideration, this research project can be readily divided into three identifiable stages with similar time allocation (see figure below). One can observe by the number of activities stacked under Step 1: the planning stage, that this step is one of the most critical and carries the greatest influence with regards to the design and execution of the study. Here the foundations are laid for a thorough and comprehensive research project, leading on to Step 2: the implementation stage, which could be said to be the main part of the study.

The diagram below (after Robson, 2002)²⁶ describes a conventional research project workflow which in general terms this study aims to follow.

²⁶ Robson, C. (2002) Real world research: a resource for social scientists and practitioner-researchers. 2nd edn. Oxford: Blackwell Publishers.

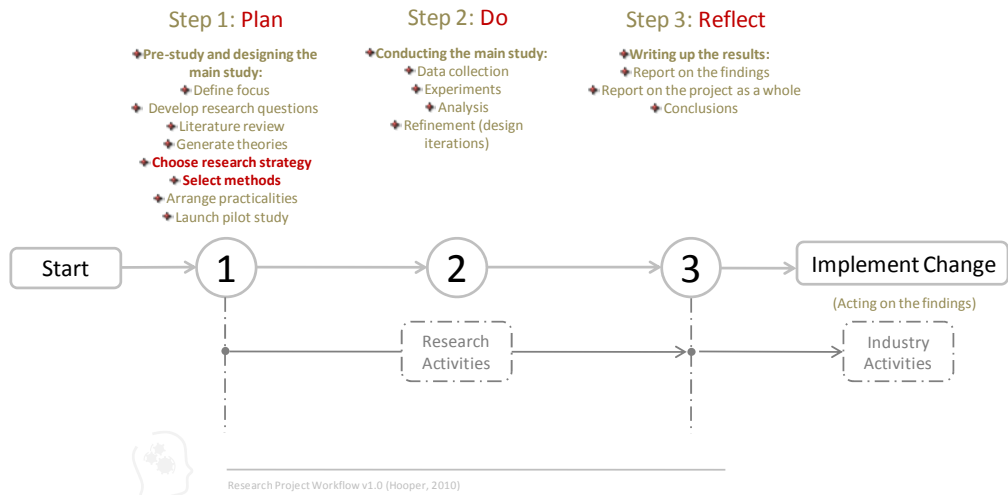


Figure 12: Research Project Workflow

A product of an evolving process, this simple framework provides a basic view of the essential organisation of the study's workflow, and facilitates the degree of flexibility necessary in this type of work.

2.3 Research Approach

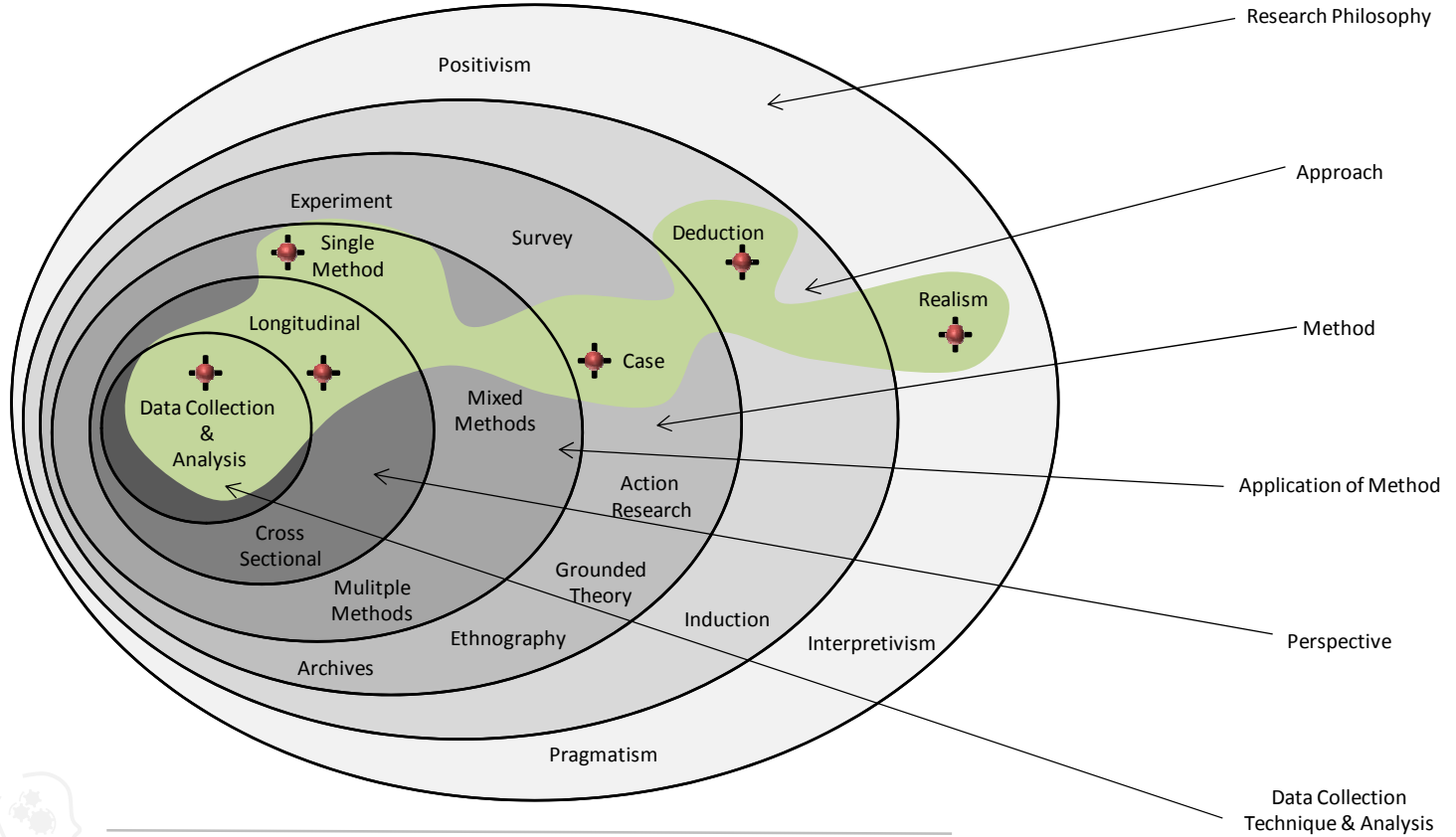
In the research world there are many different ways of perceiving both the research itself and the reality that shall be described or investigated. This has resulted in a number of research methodology guidelines, some of which either partly or wholly oppose each other. For this reason it has been important to consider the problem of selecting the most appropriate research approach from different angles to enable the possibility of describing a plausible picture.

The choice of approach should endeavour to lead the research project to the desired result where the probability of obtaining a relevant result is greatest.

Saunders (2009)²⁷ describes different approaches of research through 6 levels that can be divided into rings - like an onion – which one can scale off to reveal the core: the actual research. The layers reduce in abstraction level and become more concrete towards the core: philosophy, approach, method, application, perspective, data collection & analysis.

The figure below encapsulates these elements and indicates a preferred route to the core.

²⁷ Saunders, M., Lewis, P., Thornhill, A. (2009), *Research methods for business students*, 5th ed., Harlow: Pearson Education Ltd.



The Research Onion (after Saunders et al, 2009)

Figure 13: The Research Onion (after Saunders et al, 2009)

The research onion diagram here provides a platform to illustrate the research approach possibilities available and describe the positioning and choices made in connection to general approach and the research methodology deployed.

2.3.1 Research Philosophy

The outer circle of discussion about research and knowledge is how the researcher and the studied phenomenon relate to reality, how reality can be described and how knowledge on this reality can be evaluated – this is what is generally known as research philosophy. Here the researcher must identify where the research lies with consideration to concepts like *objectivism* and *subjectivism*, *realism* or *idealism*.²⁸

One can say *realism* and *pragmatism* lay in the middle and have an objective ground, whilst *interpretivism* and *positivism* or *constructivism* are essentially subjective in character.

Philosophic disposition adopted: The research philosophy here can best be described as critically *realistic* with an aspect of *pragmatism*. Critically realistic because it is important to not lose objectivity and to strive towards generalizability. Pragmatic because it is important to maintain focus on the research questions and purpose and utilise methods and strategies that best contribute to the answer. It is not always possible to achieve everything, and this should not be a hinder to studying, describing and interpreting phenomena, but it must be clear where a subjectively perceived reality is explored.

Part of the researcher's critical realistic disposition emanates from a career in the AEC sector and research in architecture and construction.

2.3.2 Research Approach

The approach or the strategy that is selected for the specific research project often is connected to the question of research philosophy. A popular approach is to start from existing theory then formulate hypothesis to test and verify. This suggests a deductive approach. A deductive approach implies the research happens in sequence: theory – data collection – analysis. Alternatively an inductive approach occurs through a sequence of data collection – analysis – theory. The goal here is theory building and data is collected merely with an understanding of the studied phenomena. Analysis is done through seeking patterns

²⁸ Saunders, M., Lewis, P., Thornhill, A. (2009), *Research methods for business students*, 5th ed., Harlow: Pearson Education Ltd.

within the collected data and developing, for example, categorizations that can form a base for a theory.²⁹ Deduction tests a theory whilst induction builds a theory.

Approach adopted: Since the goal here is to build on existing knowledge by testing hypothesis based on theory that may point towards answering the research questions it can be concluded that the logical approach be *deductive* in nature.

2.3.3 Research Method

The following 2 levels deal with the matter of methods and their possibility to be combined. There is a broad range of scientific methods available including *action research, grounded theory, ethnography & archives*. They are closely related to the type (quantitative / qualitative) of data sought to shed light on the problem, and have strict demands on the way the data is collected and can be used. Grounded theory for example, requires that the researcher must abandon a certain amount existing knowledge on the matter and start from the ground. Glaser and Strauss go so far to suggest that if adopted, one can never return to a research area that one earlier studied. Such a criterion demands a certain degree of knowledge waste and as such not suitable for this research project.

Experiment, survey and *case* approaches may all be suitable methods here and indeed can be mixed to form a triangulation of data. However, *experiment* with its origins in natural sciences, is most often adopted in connection with research in the physical sciences and are largely limited to the measurement and recording of actual behaviour in laboratory. They generally do not include the systematic use of survey or verbal information.³⁰ *Survey*, whilst ideal for collecting statistical data, would not function well in addressing the research questions in hand.

Finally, there is the *case* method. The *case* study approach works best when the research project involves an investigation into an issue in depth and seeks to provide an explanation that can cope with the complexity and subtlety of real life situations.³¹ It lends itself to the study of processes and relationships within a particular setting and facilitates the use of multiple methods of data collection necessary to underpin the results.

With a *case* approach one can study in depth an occurrence, activity, process and / or individual – ideal for research work within the construction industry which is concerned with people, technology and processes. Furthermore, since the construction industry from an AEC

²⁹ Saunders, M., Lewis, P., Thornhill, A. (2009), *Research methods for business students*, 5th ed., Harlow: Pearson Education Ltd.

³⁰ Yin, R. K. (2003), *Case Study Research: Design and Methods* (Applied Social Research Methods), Third Edition, London: Sage Publications.

³¹ Denscombe, M. (2008), *The Good Research Guide for Small-Scale Social Research Projects*, 3rd Edition, Maidenhead: Open University Press.

perspective is project-based, the *case* method lends itself to both discovery led and theory lead research based on investigation of case projects.

Method chosen: Against the background of method options, it has been considered appropriate to adopt a *case study* approach to tackle the research questions central to this study. The data required to shed light on these questions is largely qualitative and the case method enables the collection of such data.

The *case* method has been chosen for its capacity to find explanations to the complex circumstances that prevail between the study's objects and their connection: building information modelling, strategic planning, information exchange, collaboration. This single method together with the utilization of a variety of data collection sources has provided the backbone to address all 3 research questions.

2.4 Methods of Empirical Data Collection

Qualitative information is sought to address the research questions. The most common methods by which information is collected in qualitative case studies are interviews, observations and study of documents.³² By using multiple sources of evidence a rational of triangulation can be infused and where *converging evidence* can be established the potential problems of validity can be addressed. Multiple sources of evidence essentially provide multiple measures of the same phenomenon.³³

2.4.1 Interviews

Interviews are generally used in research to gather data on matters that simply cannot be observed or gleaned from documents. There are a variety of types of interview and it is important to select the right kind for the purpose and to seek corroboration of data received by reference to other sources. Here a combination to open-ended workshop-interviews and semi-structured interviews were used.

2.4.2 Observations

Participant observation is used by researchers to infiltrate situations, sometimes as an undercover operation, to understand the culture and process of the groups being

³² Yin, R. K. (2003), *Case Study Research: Design and Methods* (Applied Social Research Methods), Third Edition, London: Sage Publications.

³³ Yin, R. K. (2003), *Case Study Research: Design and Methods* (Applied Social Research Methods), Third Edition, London: Sage Publications.

investigated.³⁴ This method was employed to gain insight into current practice methodology relating to information exchange for 3D Design Coordination. Direct observations are a key source of qualitative information in case studies – they stand in contrast to interviews which base their data on what informants reveal and to documents where the researcher is one step away from the action.

2.4.3 Documents

In recent years there has been a proliferation of documents and articles published relating to BIM. In this respect it has been even more important to exercise prudence in assessing the validity of documentary sources in terms of authenticity, credibility and representativeness. For example, one can only be sceptical of the statistics software manufacturers claim on the promised benefits of BIM and how easy it is to deploy. However, used in conjunction with other sources, documents provided a steady leg for triangulation.

2.4.4 The Pilot Inquiry

The pilot inquiry enables the researcher to test the water with regards to the research focus and the ultimate data collection plan. Here a pilot case was examined prior to the final articulation of the study's theoretical propositions. The pilot data thus provided considerable insight into the basic issues being studied. This information was used in parallel with an ongoing review of relevant literature, so that the final research design was informed both by prevailing theories and by a fresh set of empirical observations.

2.5 Data Collected

The data collected for this study was through the aforementioned methods. Below is a description of how these methods were used to collect data to address the research questions.

2.5.1 Sampling Strategy & Analysis

The sampling strategy adopted, as mentioned, is largely qualitative. Denscombe (2008) warns that when analysing qualitative data one should *avoid introducing unwarranted preconceptions*³⁵ - personal prejudices or biases arising from practical experience or previous theories can compromise the integrity of the research. Here a balance has been attempted between drawing from own experience from practice in the field and a commitment to

³⁴ Denscombe, M. (2008), *The Good Research Guide for Small-Scale Social Research Projects*, 3rd Edition, Maidenhead: Open University Press.

³⁵ Denscombe, M. (2008), *The Good Research Guide for Small-Scale Social Research Projects*, 3rd Edition, Maidenhead: Open University Press.

grounding the results, analysis and conclusions directly in the evidence that has been collected.

2.5.2 Case Studies & Interviews

Convenience, access and geographical proximity were the main criteria in selecting the cases and collecting empirical data. This allowed for a less structured and more prolonged relationship to develop between the researcher and interviewees. The lion's share of the participants or *informants* was practitioners based in consultant practice (architects and engineers) or contracting organisations. The data was collect through 2010-2012.

Gyllins Trädgård (Paper #1)

Here documents were reviewed with particular attention placed on the buildingSMART Alliance's new Building Information Modelling Project Execution Planning Guide.³⁶ It was conjectured that it may be worthwhile testing industry appetite for such a plan in practice and a pilot case was identified to test the theory that it may help teams gain a strategic insight into the who?- what?- when?- how?- questions relating to information exchange and bridge some of the deficiencies characteristic of existing BIM guidelines in Sweden.

3 interview workshops were carried out with the focus on assessing the practicalities and general interest for implementing a standard form of BIM Planning routine leading to articulation of information exchange requirements for a variety of BIM Uses.

In a fourth workshop the findings were presenting and feedback provided.

Koggens Gränd (Paper #2)

Here attendance at 6 design coordination meetings enabled observational data to be collected with a view to both understanding what information needs to be shared and where the difficulties lie in articulating that information.

The researcher followed this project through its early stages, recording matters relating to 3D Design Coordination and collected further empirical data relating to requirements and procedures for this BIM-Use. In addition, common current practice methodologies were documented with a view to identify key issues to address. Through this case study, a thorough examination of the common issues hindering work-flow of 3D Design Coordination and early Energy Analysis operations was enabled

³⁶ Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2009), *Building Information Modelling Project Execution Planning Guide*, Version 2.0, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

Kamakura House - An Experimental Energy Analysis Model (Paper #2)

Additional case evidence was extracted from the utility of an experimental energy analysis BIM model (Kamakura House) which was later used as a teaching aid at LTH's BIM Lab.

KonsultHus - An Experimental Coordination Model (Paper #2)

For the purpose of developing an information delivery specification protocol, further case evidence was sought through the generation and examination of a controlled experimental BIM model (KonsultHus – An Experimental Coordination Model).

Empirical data reflecting the results from this experimental model, which was developed and used by the author for this study, enabled collection of further, more detailed information, eliminating unwanted variables, and facilitating a more precise examination of objects and properties required for 3D Design Coordination.

Interviews & Sector Discussions (Paper #3)

Focus group interviews (FGI's) were used in connection with Paper #3, which dealt with contractual hindrances to BIM collaboration, to probe industry representatives' opinions and extract responses to the theory that existing forms of construction contract and consultant appointment forms do little to support the collaboration implied at the core of BIM implementation and indeed present a hinder to a number of essential processes.

Further more informal discussions involving other industry representatives provided additional insight and helped validate results.

2.6 Reliability, validity and generalization

Case study research is notoriously dubious to generalize from. However a number of separate considerations and mitigating measures can ensure results and the conclusions draw from them are well placed:

✦ Reliability:

Reliability refers to the ability to replicate the results. In qualitative research, since the phenomenon under study is dynamic, replication is problematic. The issue of reliability however can be addressed to some extend by selecting cases and collecting data that can be deemed *representative*. In this respect the cases selected do carry characteristics that are *typical* which can be seen to support the propensity of data collection that is representative and that can be relied upon.

✦ **Validity:**

Internal validity refers to judgement of whether the collected data is valid or not. Internal validity describes how congruent the findings are with reality. Merriam (2006) notes that in qualitative research, *the understanding of reality is really the researcher's interpretation of the participants' interpretation or understanding of the phenomenon of interest.*³⁷

To increase the internal validity of the work, the following methods were employed:

- ✦ Triangulation by collecting data through multiple sources.
- ✦ Peer-review with feedback sessions.
- ✦ Intermediate presentations of findings and results to industry interest groups, with feedback.

✦ **Generalization:**

External validity or *generalizability* in qualitative research can be interpreted as the extent to which the findings can be applied in other situations. Merriam (2006) suggests that: *the general lies in the particular; what we learn in a particular situation we can transfer to similar situations subsequently encountered.*³⁸

Here, to address the matter of generalizability it is suggested that whilst the restricted number of case projects investigated somewhat limits the possibility to generalise from the results, the construction projects themselves (although in some respects unique) can be deemed typical examples of the kind of construction project representing the practice and output of today's DCO sector. The phenomena observed, when considered in qualitative terms, can thereby be regarded appropriate to draw the strategic conclusions sought.

³⁷ Merriam, B. (2006), Fallstudien som forskningsmetod, Studenttiteratur, Lund.

³⁸ Merriam, B. (2006), Fallstudien som forskningsmetod, Studenttiteratur, Lund.

On theory:



"A theory must be tempered with reality." (Jawaharlal Nehru)³⁹

3.0 Theory

As a whole the study should be based on a solid theoretical framework supported by empirical findings from test cases. A product of literature review, this section presents the underlying theory behind this study and introduces a number of key concepts that have had a direct bearing on the research questions.

Although here presented after *methods* and *data collection*, theory has had a key role to play in forming the research questions which in turn inform the decisions around choice of method and means of collecting information. Theory also forms the background to the findings and, further to those issues outlined within the introduction, here provides something of a springboard to launch the empirical work.

³⁹ Jawaharlal Nehru (1889-1964) Indian Prime Minister 1947-64

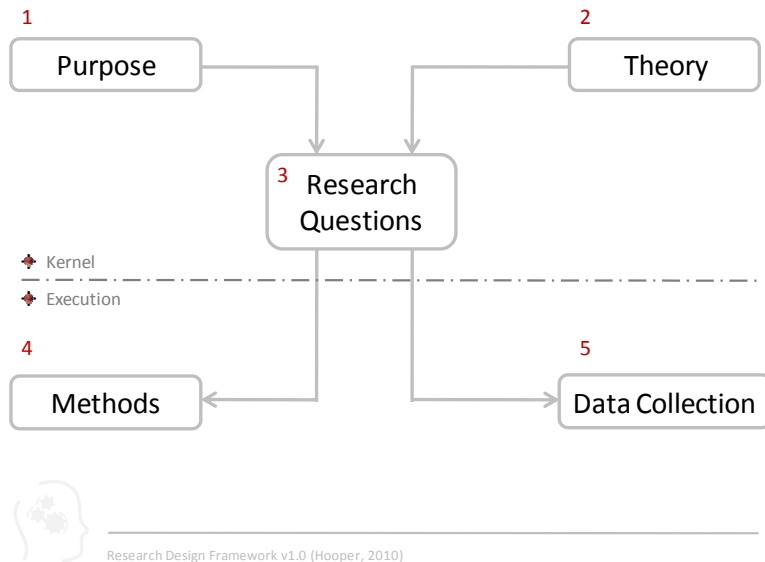


Figure 14: Research Design Framework

This section attempts to present the theory built up of 3 main threads: *standards & guidelines*, *digital delivery specification* and *forms of agreement*, set against a background of existing circumstances.

3.1. BIM and the DCO process today

Building Information Modelling (BIM) is driving an unprecedented revolution in the construction industry. It involves using digital modelling software to more effectively design, build and manage projects, and is providing powerful new value to the construction industry firms that adopt it. Simultaneously, it is breaking down age-old barriers between these players by encouraging the sharing of knowledge throughout the project lifecycle and closer collaboration to integrate valuable fabrication, construction and operations expertise into the overall design. This improves constructability, adherence to schedule and budget, lifecycle management and productivity for everyone involved.⁴⁰

⁴⁰ McGraw Hill Construction (2008) SmartMarket Report: *BIM - Transforming Design and Construction to Achieve Greater Industry Productivity*, New York: McGraw Hill Construction.

Today the construction industry in Sweden represents 8% of GDP, equivalent to 250 billion Swedish Kronor.⁴¹ OpenBIM⁴² representatives determine that several billion Swedish Kronor can be saved in the Swedish construction sector, representing nearly 30%.⁴³

According to McGraw Hill Construction's SmartMarket Report, 70% of BIM users say more clearly defined BIM deliverables between parties is highly to very highly important to increasing the value of BIM within the sector.⁴⁴ Beyond the issue of interoperability (that has compromised both productivity and the value of the building design and construct information since the advent of CAD) sorting out objectives around information exchange, deliverables and collaboration remains both a theoretical and practical challenge.

It is claimed for example that one has to enter the same data 7 times through the design and construction process.⁴⁵ Ultimately the information that may be available and accessible through a facilities *operate* phase may be either irrelevant or inaccurate.

In addition, Sweden's OpenBIM representatives point out:

*"There is neither a central directive nor common guidelines [in Sweden] which leads us to sub-optimized and unnecessary costs for [construction] energy and the environment and poor competition development."*⁴⁶

With a background of a theoretical promise of much to gain together with a fog of practical uncertainties and difficulties, the integration of BIM into the DCO process today presents an opportunity to deliver on improving important aspects of construction industry practices.

3.1.1 The need for improvement

Sweden lies behind its Nordic neighbours and the US when it comes to implementing national standards in connection with BIM. In order not to continue to lose competitiveness in international markets it is essential that BIM is adopted and implemented consistently.

⁴¹ Statistics Sweden & Isaksson, F (2011) *The Swedish Construction Sector and a Short term Economic Outlook*, The Swedish Construction Federation, Stockholm.

⁴² OpenBIM is a not-for-profit organisation promoting and supporting the use of BIM in Sweden, also see: www.OpenBIM.se

⁴³ Anderson, R. (2010) VVS-Forum #2, February 2010, Stockholm, also see: www.OpenBIM.se

⁴⁴ McGraw Hill Construction (2008) SmartMarket Report: *BIM – The Business Value of BIM: Getting Building Information Modelling to the Bottom Line*, New York: McGraw Hill Construction.

⁴⁵ Edgar, J.O.(2008) ByggIndustrin - *Brist på samordning hotar BIM* – Jan 2008 - <http://www.byggindustrin.com> – extracted October 2011.

⁴⁶ Lindström, M. & Jongeling, R (2012) *Nationellt Initiativ för Digital Information - För ett bättre samhällsbyggande*, OpenBIM Presentation.

This may involve identifying and standardising those BIM concepts and processes that are key to avoiding divergence in methodology.

That's not to say that standards don't exist and DCO players are just making their way blindly. There are a number of organisations in Sweden that are leading world and have produced a number of exemplar projects using BIM technology and appropriate methodologies. But there are also a lot *just making rules up as they go along* and still some who think BIM is just 3D visualisation on steroids.

DCO players need help to get the best out of BIM, not just to leverage the benefits of BIM but more importantly enabling teams to do the best for the project.

Such standards go beyond office boundaries and can be applied consistently to entire the projects through not just design or construction, but the complete lifecycle to FM, refit and decommissioning.

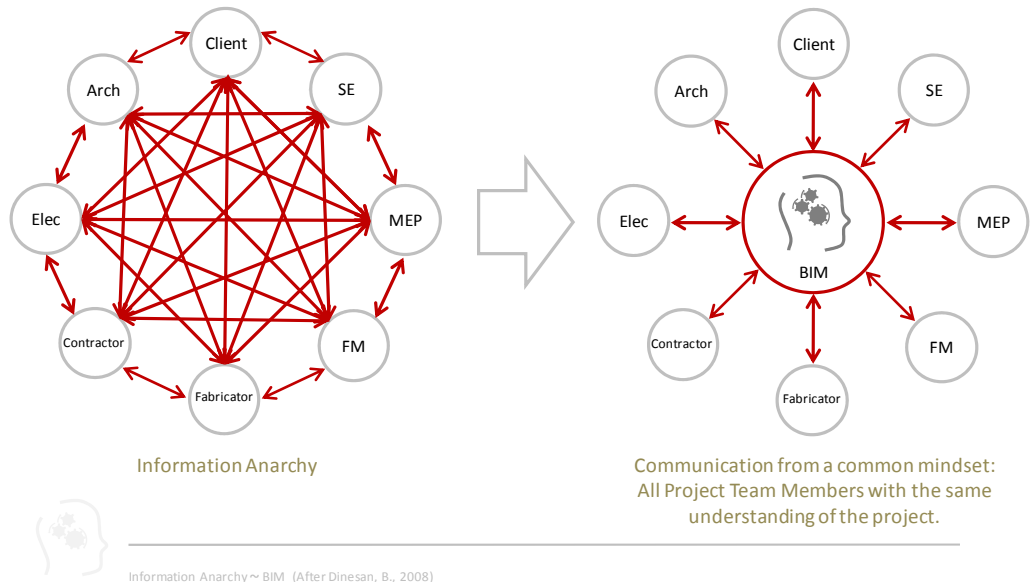


Figure 15: Information Anarchy to BIM (After Dinesan, B., 2008)

From the relative information anarchy that prevailed pre-BIM, it is a quantum leap to implement BIM in a way that allows all project team members to communicate in such a way that enables a common understanding of the project. However, this may be where the *need* for improvement lies.

3.1.2 Scope for improvement

The construction industry is seen by many as a problem sector.⁴⁷ The British *Egan Report* (1998)⁴⁸ and the Swedish *Skärpning Gubbar!* (2002)⁴⁹ being testimony to this. Follow-up reports, *Construction Excellence, 10 years since Egan* (2008)⁵⁰ and *Sega gubbar?* (2009)⁵¹ both moreover suggest that not much has improved since then. However, one can pick out a number of resent high-profile construction projects that have been resounding success stories. Öresundsbron 2005, and Malmö City Tunnel 2010, for example, were both technical and economic success stories where the crucial factors, time and budget, were maintained or bettered.

The construction sector has had a tendency to harbour certain paradoxes but one thing is for sure, the use and integration of ICT in the AEC sector together with the volume and value of data is destined to rise. It often leads to great frustration when one compares or attempts to benchmark the construction industry with, for example, the auto industry or mobile phone industry that, as such, have managed to achieve so much more with the use of similar technologies. The scope for improvement here may lie more in the actions of the DCO participants and the use of the data than the technology itself.

3.2 Standards & Guidelines

There is general agreement in the sector that methodological, procedural and modelling standards are essential to successful implementation. Resultantly there are a number of important national standards and BIM implementation guideline documents now emerging around the world including the NBIMS⁵², bips⁵³ and the NGDM⁵⁴. These and others are reviewed and reported on in more detail latter, however, presented below are a number of standards (initiatives) and guides that come to have a significant theoretical bearing on the research matter.

⁴⁷ Landin, A. & Lind, H. (2011) Hur står det egentligen till med den svenska byggsektorn? – Perspeciv från forskarvärlden, Kalmar: Lenanders Grafiska.

⁴⁸ The Construction Task Force (1998) The report of the construction task force, Rethinking construction (The Egan Report), Department of Trade & Industry, London.

⁴⁹ Bygghögskolekommittén (2002) *Skärpning Gubbar!, Om konkurrensen, kvaliteten och kompetensen i byggsektorn*, SOU 2002:115, Fritzes offentliga publikationer, Stockholm, Sweden.

⁵⁰ G4C (2008) *Construction Excellence, 10 years since Egan*, Department of Trade & Industry, London.

⁵¹ Statskontoret (2009) *Sega gubbar? En uppföljning av Bygghögskolekommitténs betänkande "Skärpning gubbar!"*, Statskontoret, rapport 2009:6.

⁵² NIBS (National Institute of Building Sciences). (2007), National Building Information Modeling Standard - Version - Part 1- Overview, Principles, and Methodologies, NBIMS, US.

⁵³ bips (2006), 3D Arbejdsmetode 2006. Denmark: bips.

⁵⁴ CRC Construction Innovation (2009), National Guidelines for Digital Modelling, Brisbane: CRC.

3.2.1 buildingSMART Alliance Initiatives

The scope and diversity of building industry standards development efforts around the world are vast. Multiple initiatives by numerous organisations are underway, synonymous of the fact that there are many challenges that need to be addressed. Here it is important to consider this work in the context of the bigger picture and specifically it's relation to the ongoing efforts and long-term goals of the buildingSMART alliance.

The buildingSMART alliance (previously known as the IAI⁵⁵) has the broad mission to serve as a forum for the coordination of the work of standards development groups and a large number of international research and development projects. It is a neutral international organisation that supports open BIM through the DCO lifecycle.⁵⁶ They develop and maintain international standards and technical solutions relating to process and product.

Among the foundational standardisation efforts of the buildingSMART alliance and its worldwide counterparts are the *Information Delivery Manuals* (IDMs) and *Model View Definitions* (MVDs). These are examples of the sector's collective recognition that better information is needed to support the development of better tools now emerging to deliver construction projects.⁵⁷ Technologies such as IDM and MVD are intended to help identify exactly what that information is by defining, for example, a model definition view for automated code checking and the information that must be included to generate that view. This work is ongoing and as such is still a long way off being available for all DCO participants; as is the full capabilities of the *Industry Foundation Classes* (IFC)⁵⁸.

One of the aims of this study is to contribute towards the development of IDM's and MVD's by helping DCO players articulate their information needs through the DCO process. However, whilst buildingSMART is largely concerned with technical solutions, this work attempts to present a number of small scale practical interventions that DCO participants can perform to address a number of key challenges.

This study must be viewed in the context of industry initiatives such as that of buildingSMART and whilst much of the integrated technical solutions heralded have still to reach maturity

⁵⁵ International Alliance for Interoperability

⁵⁶ <http://buildingsmart.com>

⁵⁷ Smith, D and Tardif, M. (2009), *Building Information Modeling: A Strategic Implementation Guide for Architects, Engineers, Constructors, and Real Estate Asset Managers*, John Wiley & Sons.

⁵⁸ There has been significant resistance by a number of mainstream software AEC vendors to fully embrace the IFC data standards and resolve the matter of interoperability, for amongst other reasons, to assert and maintain market domination. This has manifested in half-hearted implementations, leading to a dilution of trust for IFC as an exchange format amongst users. However, to date, utilization is increasing by virtue of the need for open standards and improving functionality.

and full mainstream implementation, there is much wisdom to be gained from ideas behind buildingSMART's initiatives which claim to be market-driven.

This study conjectures that, notwithstanding the possible technical solutions for information management on the horizon, rather than waiting or relying on external agents to sort out internal information management issues, DCO organisations must focus on what they can do, both individually and collectively to embrace BIM. This may include reaching a rational consensus for standardized *administrative* and *strategic* BIM protocols. Whilst the long term vision of buildingSMART's initiatives is one thing, short-sighted and operational challenges still loom large. Perhaps the challenge is on the short-term playing field where the focus is on *here and now* solutions.

3.2.2 Bygghandlingar 90

Bygghandlingar 90 (BH90),⁵⁹ a product of the Swedish Standards Institute,⁶⁰ is represented through a series of documents (1-8) intended to provide the construction industry with guidance and standards on the production of construction documents. Part 8: Digital deliverables for construction and facilities management⁶¹ represents Sweden's chief guidelines for delivering digital information in connection with construction projects and is a valuable source of direction providing logical recommendations for managing building information in an organized and careful manner.

The BH90 series can be described as *administrative*. Part 8 can be considered as a modest extension of the CAD guidelines it replaced and attempts to establish a standard recommended method of information flow between teams through design stages. It also describes a method of information exchange making it of relevance to a broader range of DCO participants.

However, it does not represent a BIM Standard and requires some development in a number of areas including that of BIM-Info Delivery Specifications. Part of the output from this study aims to provide practitioners with a useable tool to address this deficiency and help the industry move towards procedural standardisation. In addition, BH90 lacks a strategic standard method of planning and agreeing amongst project team members a process of BIM implementation with a focus on common goals and information exchange.

⁵⁹ www.bygghandlingar90.se

⁶⁰ www.sis.se

⁶¹ SI, Swedish Standards Institute (2008), *Bygghandlingar 90 : byggsektorns rekommendationer för redovisning av byggprojekt*. D. 8, Digitala leveranser för bygg och förvaltning, Stockholm : SIS Förlag AB.

3.2.3 The BIM PEPG

With BH90 offering little support for strategic decision making in the context of the use of BIM technology on a project basis, it was thought apt to attempt, through a review of existing BIM guideline documents to be found around the world, to identify what kind of additional supporting documents might be relevant to the Swedish DCO sector.

The buildingSMART Alliance's new *Building Information Modelling Project Execution Planning Guide* (the BIM PEPG) was identified as a document that may provide a smart solution to address a number of the deficiencies of BH90 and help organisations develop their BIM maturity.

The BIM PEPG is a product of the BIM Project Execution Planning buildingSMART alliance™ Project and was developed to provide a practical methodology for project teams to design their BIM strategy and develop a *BIM Project Execution Plan*. The main concepts behind the guide have been developed to complement the long term goals of the buildingSMART alliance in the development of a standard that can be implemented throughout the AEC & FM industry to improve efficiency and the effectiveness of BIM implementation on projects.⁶²

The BIM PEPG may be considered a *strategic* guide. Teams can deploy a BIM plan⁶³ as a collaborative tool for establishing project standards (particularly important where participant's / organisation's BIM capability and maturity is at variance) and alignment of project-based goals and objectives. The BIM PEPG also helps teams define the roles and responsibilities for each team member, what types of information to create and share, and what infrastructure resources (people & equipment) may be required. The BIM PEPG can be implemented through 4 straight-forward steps.

⁶² Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2009), *Building Information Modelling Project Execution Planning Guide*, Version 2.0, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

⁶³ Another example is: Autodesk (2010) *Autodesk BIM Deployment Plan: A Practical Framework for Implementing BIM*, Autodesk: California.

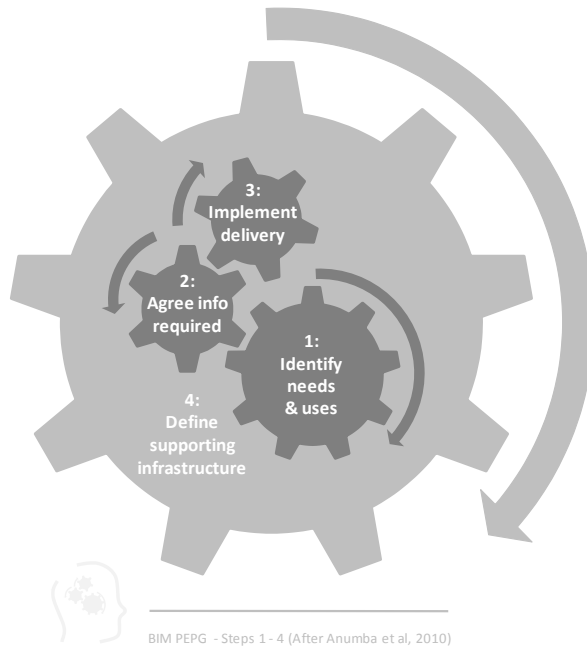


Figure 16: BIM PEPG: Steps 1 – 4 (After Anumba et al, 2010)

With a proper BIM plan in place from the start, players can help keep the BIM data intact and useful through the design – construct – operate process, ensure opportunities are not wasted, and that real value is added to the project.

The BIM PEPG is tested through a pilot study reported on through Paper #1: A Pilot Project - Toward BIM Integration - An Analysis of Design Information Exchange & Coordination.

3.2.4 In-House BIM Manuals

In the absence of national BIM standards in Sweden, DCO organisations have considered it prudent to consider building their own standard solutions.

Typically in-house manuals contain varying levels of guidance and templates for making decisions on:

- ✦ BIM Planning
- ✦ General modelling requirements & conventions (with reference to other standards).
- ✦ Discipline specific modelling requirements.
- ✦ Modelling Rules for creating models for specific uses, eg: Quantity Take-off, Energy Analysis, etc.

However, they often lack consistent means to agree on:

- ✦ A collective, project specific BIM strategic plan.
- ✦ BIM-Delivery Schedule.
- ✦ BIM Authorised Uses Schedule.
- ✦ Level of Detail Schedule at each Stage.
- ✦ Object Author Matrix.
- ✦ Collaboration Protocol.

It is conjectured that, in the national interest, a number these concepts and implementation decision making processes should be standardized and in the public domain to avoid unnecessary divergence of methodological approach that may lead to compromised cross-border competition.

3.3 Digital Delivery Specifications

Definitions of digital information deliverables for specific BIM-Uses still remain something of puzzle in practice today. Too much guess-work still exists and as such BIM information deliveries could be better organised and potentially standardised.

BH90 outlines the concept of *Leveransspecifikationer* (Digital Delivery Specifications) but it remains a somewhat abstract idea and concrete examples are lacking. BH90 recommends the use of delivery specifications to accompany exchanges in digital information at all stages of the design, construct and operate process.

The Swedish organisation Föreningen för Förvaltningsinformation (FFI) has developed a form of *Leveransspecifikationer* specifically for enabling standard delivery of information for FM purposes. The result is a plug-in tool that can extract model content (from presumably an as-built record model) in the form of drawings, models, calculations etc in fi2xml format. A limiting feature of this development is that it is not designed as a collaboration tool to enable BIM information content authors (Architects and Engineers) to align information content requirements against planned BIM-Uses.

It is suggested here that a new form of BIM-Info delivery specification could be developed to help align information delivery expectations to offer the control, confidence and simplicity necessary for a more effective information exchange process to be realized.

3.4 Forms of Agreement and BIM Collaboration

Changes in business processes will inevitably result in significant changes of business and contractual relationships. To restrain a new way of doing business with outdated forms of

business relationships would be not only foolish but costly, and would keep us from realizing the full potential of BIM.⁶⁴

Whilst technology has enabled a whole new level of collaboration through the use of proprietary BIM tools, the industry has some catching-up to do in terms of contracts, liabilities and risk management. To take advantage of new BIM technologies beyond the boundaries of one's own organisation, changes in project organisation, workflow practices are inevitable; *'Everything has to be done in a more collaborative and structured way, and that's where the real challenges lie'*.⁶⁵ *'A true and functioning BIM-Workflow demands new forms of collaboration and responsibility'*.⁶⁶

Around the world new contract forms that are being developed today are driven by a desire for greater clarity, increased confidence between parties, better conditions for cooperation and shared responsibility. In Sweden, a number of major contractors are developing various forms of transparent construction contract with clients - partnering solutions – which demonstrate a desire for greater collaboration and can be seen to represent a move toward IPD, however it is conjectured that the AB⁶⁷ family of standard contracts represent something of hinder to BIM collaboration and better supporting mechanisms are needed.

3.5 Construction Classification

Construction classification plays a key role in the industry, not least in connection with BIM. Classification systems organise construction project information into views, for example, building parts, activities or production results.

Standardisation of information is essential to proper leverage of information within a BIM project. The information contained in models must be universally understandable and accessible; otherwise it is useful only to the individuals who populated the model with that information. A standard taxonomy of construction and design terms allows information to be exchanged with the knowledge that it will be understood by others.

⁶⁴ Smith, D and Tardif, M. (2009), *Building Information Modeling: A Strategic Implementation Guide for Architects, Engineers, Constructors, and Real Estate Asset Managers*, John Wiley & Sons.

⁶⁵ Benedict Wallbank, (2011) *RIBA Journal*: July / August 2011, RIBA, London.

⁶⁶ Argéus, J., Hasselberg, P. (2011) *BIM för Analysis och Dimensionering, Examensarbete*, Department of Structural Mechanics, Lund University, Lund. Original form: 'Ett äkta BIM-arbetsflöde kräver därför helt nya samarbets- och ansvarsformer'.

⁶⁷ Allmänna Bestämmelser (General Conditions of Contract) which includes: ABK 09, AB 04, ABT 06.

The international standard for building classification is manifested in SS-ISO 12006-2. This standard is reflected in the Swedish BSAB 96 building classification system as well as a number of other more internationally well known systems like OmniClass.

Since the advent of BIM, formats are being developed that lend themselves to use within BIM modelling platforms. OmniClass for example, has series of formats and standardised tables that allow information captured within a model to be organised to its simplest level and cross-referenced in a variety of ways.

Whilst not all OmniClass tables will find their way into a BIM (many of the tables are more of a higher-level project management nature), the ones that are considered to have the most bearing are: Table 21 – Elements, Table 22 – Work Results, Table 23 – Products and Table 49 - Properties.⁶⁸

Certain difficulties have been voiced regarding the use of BSAB classifications in BIM projects in Sweden, which has resulted in discreet auxiliary methods of identifying objects (tagging) critical for automated cost estimation⁶⁹. Amongst other things, this study aims to identify deficiencies.

Work is ongoing⁷⁰ to adjust and orientate BSAB to BIM projects led by industry and academic experts⁷¹

3.6 Interoperability

No single computer application can support all the tasks associated with building design, production and FM.⁷² For this reason applications must be able to import and export data (ideally seamlessly) to allow data about a building to be used intelligently downstream.

Interoperability depicts the need to pass data between applications, allowing multiple types of experts and applications to contribute to the work and flow of DCO digital information. Poor interoperability continues to be an enormous burden to the industry. However, data model standards have improved thanks to the work led by the ISO-STEP international standards effort.

⁶⁸ Waygant, R. (2011), *BIM Content Development: Standards, strategies and best practices*, John Wiley & Sons: New Jersey.

⁶⁹ OpenBIM (2011), *OpenBIM effektiviserar bygg- och förvaltningsprocesserna*, OpenBIM Seminarium, Stockholm.

⁷⁰ Including a new research project within Svensk Byggtjänst.

⁷¹ Including: Professor Anders Ekholm, Lund University and Jan-Olof Edgar, CIO, Projektengagemang Byggprocessstyrning AB.

⁷² Eastman, C., Teicholz, P., Sacks, R., Liston, K. (2008), *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*, London: John Wiley & Sons.

Today, one of the main building product data models are the *Industry Foundation Classes* (IFC) which can handle data for building planning, design, construction through to FM. IFC can represent geometry, relations, processes and material, performance, fabrication and other properties needed for design and construction.

Functioning interoperability imposes a new level of modelling rigor that organisations still need to get to grips with. Objects require to be modelled with the correct tools, labelled in the correct and consistent manner, display correct and appropriate properties and have the correct relationship to other objects.⁷³

There are many ongoing debates over the use and reliability of IFC (in which the competence level of the user and incomplete software implementation can be considered as factors) and in attempts to circumnavigate interoperability issues, certain important clients have been known to insist on the use of particular software platforms to enable consistent use of native formats.

A high level of interoperability is desirable and indeed high priority to enable teams to foster a culture of information stewardship. However this remains a technical problem that DCO players cannot solve themselves.

3.7 BIM as Socio-technical System

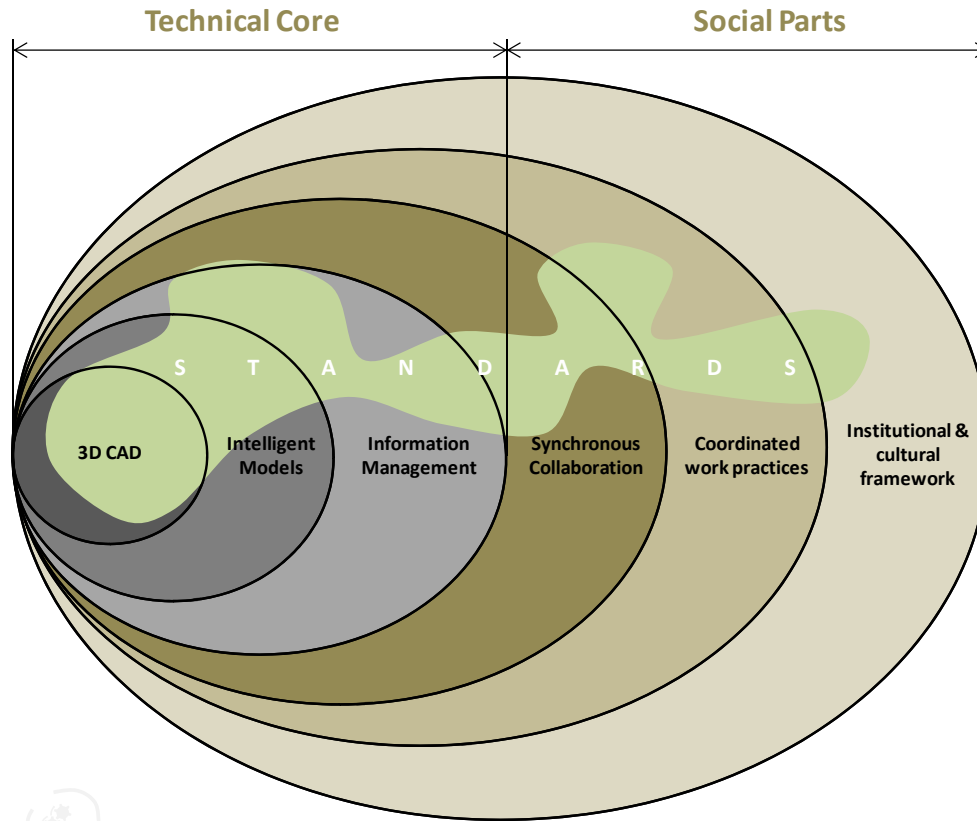
A socio-technical system exists where man and machine come together to operate in society. It tends to have a technological *core* and a societal component - it is represented by the combination of man-made technology and the social and institutional consequences of its implementation in society⁷⁴.

BIM is an example of a socio-technical system. It's a *system* because it could be described as a unified entity consisting of many interacting parts, some physical, some soft. It's *socio-technical* because it has social components, complementing the technical core.⁷⁵ The diagram below illustrates what a BIM socio-technical system may comprise.

⁷³ Björk, B-C., (2008), Interoperability in Practice: Geometric Data Exchange Using the IFC Standard, ITcon Vol.13 (2008).

⁷⁴ The telephone network is a well-known example of a socio-technical system. It is not only technology and users; it contains associated behaviours, social norms, and certain kinds of relationships and cultural institutions.

⁷⁵ WSP & Kairos Future (2011), Ten truths about BIM – The most significant opportunity to transform the design and construction industry, WSP & Kairos Future, Stockholm, Sweden.



BIM as Socio-technical system (after Kairos Future & WSP , 2011)

Figure 17: BIM as a Socio-technical System (after Kairos Future & WSP, 2011)

The new social and cultural institutions implied with BIM implementation are both interesting and important areas to consider, and viewing it as a socio-technical system may offer clues as to how adoption can be integrated within AEC society with minimal struggle. Standards, as in other socio-technical systems, may come to have significant bearing on the behavioural aspects of the new working practices associated with BIM and ultimately on the success levels of implementations.

3.6 Push & Pull of BIM Implementation

The diagram below provides an example of the push and pull elements of BIM implementation that, amongst others, the UK government⁷⁶ suggest are necessary for both widespread adoption and a more integrated construction industry.

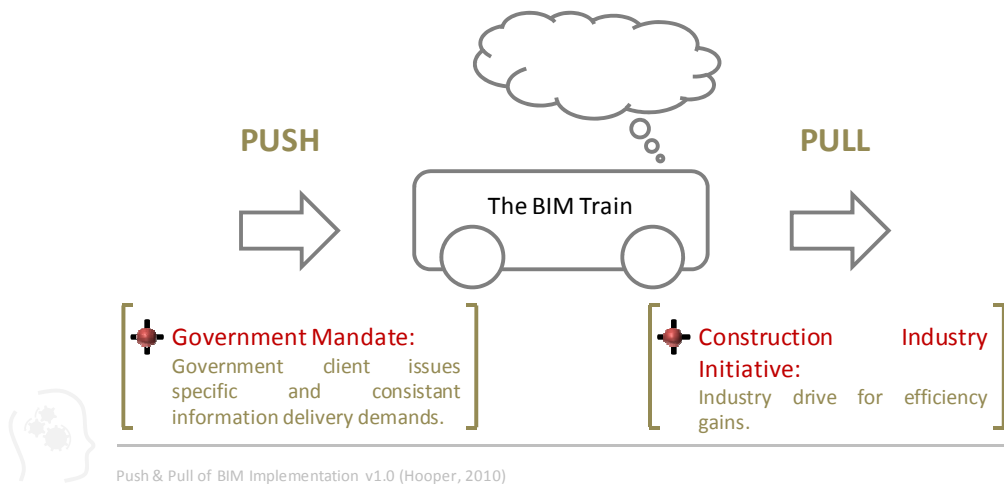


Figure 18: Push & Pull of BIM Implementation

Here in Sweden there is strong evidence of ‘pull’ through construction industry initiatives; OpenBIM for example, and investment and leadership demonstrated by the construction giants (NCC, Skanska, Peab & JM) together with significant resources deployed by the larger consultant organisations (Tyréns, White, Tengbom & FOJAB). On the ‘push’ side however there is a rather passive drive to implement BIM on *building* construction projects.

In Sweden, the general view is that the main drive for BIM implementation is not so much through client demand but rather motivated by a relatively small number of technically

⁷⁶ UK Government BIM Industry Working Group (2011) BIM Management for value, cost & carbon improvement - A report for the Government Construction Client Group – Building Information Modelling (BIM) Working Party Strategy Paper, London, UK.

orientated enthusiasts.⁷⁷ This contrasts however with *infrastructure* construction sector where the likes of Trafikverket⁷⁸ now insist on the use of BIM amongst design and construction participants.

It is worth noting that the push and pull balance of BIM implementation in Sweden differs from that of its Nordic neighbours, in fact can be said to be unique in the region which may come to have a bearing on the nation's propensity to succeed in adopting BIM in a consistent way.

Furthermore, according to Samuelsson (2010)⁷⁹ amongst design consultant organisations the initiative behind BIM implementation appears largely to be bottom-up in orientation, where individuals or groups who are involved in the creation of design material for construction (construction documents) have developed an interest in using smart tools and follow the general development of working methods, software tools and standards. Amongst contractors, however, the lead is coming from management level.

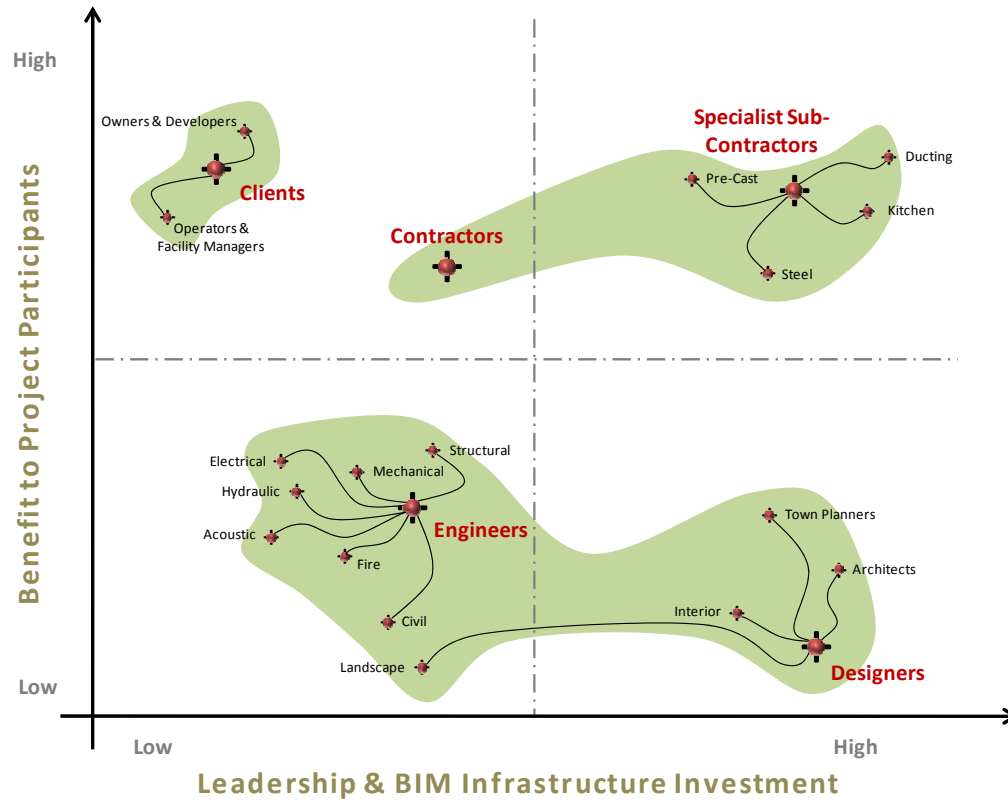
The graphic below (after Succar) serves as a reminder that those investing in BIM infrastructure (being people, technology and processes) are not necessarily those who stand to gain the most. Governments, as large facilities owners, have much to win and leadership is key to successful implementation at national level.

Here, the underlying theory is that although not all organisations have the same to gain, participation (including leadership and investment) in the processes that may ensure optimal integration of BIM affects all. Engagement from all levels (bottom-up / top-down), together with a suitable balance of push and pull to motivate DCO players to do their best for the sake of the project may be a deciding factor of success or failure.

⁷⁷ www.openbim.se

⁷⁸ Trafikverket is a state organisation responsible for national infrastructure including roads, bridges and railways. They now (2012) have a strategic policy to insist on BIM on contracts over a certain value.

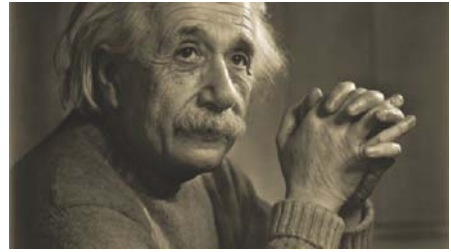
⁷⁹ Samuelson, O. (2010), *IT-innovationer i svenska bygg- och fastighetssektorn – En studie av förekomst och utveckling av IT under ett decennium*, Hanken School of Economics, Helsinki.



Benefit v. Investment (After Succar, 2010)

Figure 19: BIM Implementation: Mapping Beneficiaries v. Infrastructure Investment

On findings:



"A man should look for what is, and not for what he thinks should be." (Einstein)

4.0 Findings

In this chapter the main findings are presented from the case material examined and provide insight into research question refinement. The object here is to merely present the facts.

4.1 Summary and Results from the Appended Papers

The main findings from the separate studies designed to address the research question are herein presented. The full papers are appended at the back of this thesis; the summary version below is based on the content of these works.

4.1.1 Paper I: A Pilot Study: Towards BIM Integration - An Analysis of Design Information Exchange & Coordination

Introduction

Construction projects are becoming increasingly complicated in nature, requiring more specialist discipline input resulting in a much greater volume of technical information which in turn requires to be coordinated and kept up-to-date and relevant through the life cycle of a project. In such contexts conventional project filing systems and information work-flows are becoming un-manageable and there appears to be a need for user friendly practice guidelines to supplement existing standards which if adequately tested, could form a key part of an Information Delivery Manual (IDM) or even a National BIM Standard.

In Scandinavia, where construction is generally more expensive than in central and southern regions of Europe⁸⁰, there is a concern expressed throughout the industry that building

⁸⁰ Statistics Sweden: <http://www.scb.se/>, visited December 2009.

productivity must be increased. In conjunction with the new processes implied by BIM for design delivery, construction and facilities management, an industry-informed information exchange protocol should be able to contribute toward providing better value.

BIM, amongst other things, seeks to streamline processes, present construction information in an accessible and common way, minimise the possibility of missing or clashing information and ensure optimised project coordination. The real value of BIM to any organisation be it a design firm, construction firm or building owner, is in leveraging the structured information contained in a building information model to create value.⁸¹

To implement BIM and tap into leveraging efficiency benefits an organisation must first consider a critical evaluation of its core competencies and business objectives, followed by strategic deployment of appropriate technology to take the guesswork out of business decisions and shift the organisation's output from traditional routine, low-value-added tasks and services toward high-value-added tasks and services.⁸²

For design firms, this means investing in tools and implementing business processes that are essential to increasing efficiency, productivity, profit, and value. There is a need for a new focus on providing sustained value to clients, eliminating or reducing inefficiencies in the process and eliminating repetitive and mundane tasks.

Purpose

Many business aspects are affected through full and effective BIM implementation. By viewing the implementation process and the act of exchanging information as a role of information stewardship,⁸³ this study aims to test and reveal the results of mechanisms facilitating and constraining BIM integration through an analysis of identified BIM uses, designed implementation processes and developed information exchanges.

This objective is pursued by: 1) a study of a residential construction project with a major architectural practice in Sweden; 2) a series of workshops with design consultant participants involved in the development and use of BIM in connection with the studied project; 3) an

⁸¹ Jernigan, F. (2008), *BIG BIM little bim: The Practical Approach to Building Information Modeling-integrated Practice Done the Right Way!*, Booksurge LLC; 2 edition.

⁸² Smith, D and Tardif, M. (2009), *Building Information Modeling: A Strategic Implementation Guide for Architects, Engineers, Constructors, and Real Estate Asset Managers*, John Wiley & Sons.

⁸³ Smith, D and Tardif, M. (2009), *Building Information Modeling: A Strategic Implementation Guide for Architects, Engineers, Constructors, and Real Estate Asset Managers*, John Wiley & Sons.

analysis of empirical data collected by the application of the buildingSMART Alliance's new *Building Information Modelling Project Execution Planning Guide* (the BIM PEPG).⁸⁴

One of the first steps in any research process is to assess the potential for improvement in order to tune the study focus towards a defined purpose in which a valuable contribution towards development in the field can be realized. The purpose of this initial pilot project is amongst others: to measure and evaluate how far BIM has come in practice; to identify issues of information exchange; to record current practice methodologies; and to explore possibilities for improved efficiency and error mitigation.

The diagram below, based on Eastman et al (2008) illustrates the comparative effects of traditional information exchange practices versus that with effective use of BIM technology. The first thing to highlight is that traditional practices contribute to unnecessary waste and errors.⁸⁵ The impact of poor information flow and redundancy is illustrated by gaps (being for example, by discrepancies or contradictions) in project documentation when transferred between actors and / or phases.

Whilst this *information degradation* in part may be attributable to poor interoperability, it can also be a function of simply authoring the wrong information at the wrong time and constitute waste as a result of re-work.

As part of a sincere BIM effort, it is suggested therefore that early in a BIM workflow teams must: 1) identify BIM Uses, 2) Agree info required, 3) implement delivery.

Instances of BIM information exchange are highlighted along the BIM – effort curve. Here it is critical to understand what deliveries are required by whom and when.

⁸⁴ Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2009), *Building Information Modelling Project Execution Planning Guide*, Version 2.0, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

⁸⁵ Eastman, C., Teicholz, P., Sacks, R., Liston, K. (2008), *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*, London: John Wiley & Sons.

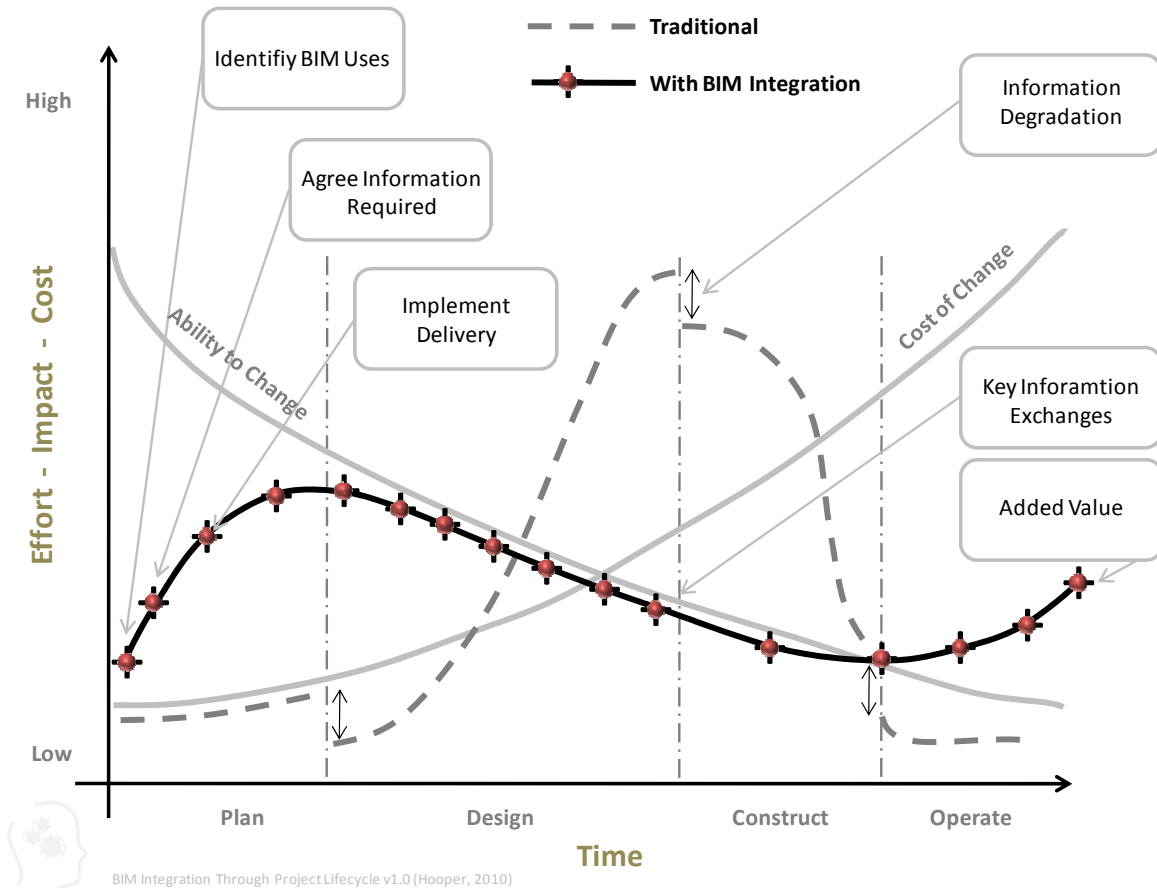


Figure 20: BIM Integration through Project Lifecycle (After Eastman et al, 2008)

The theory behind BIM provides an exciting integrated solution for project information management; however, in this new process a number of key questions need to be resolved: Who is involved? What models are required and why? When are the models needed? What should the models contain? How are the models exchanged? Who manages the process? The BIM PEPG enables teams to address the matters and agree a way forward. This paper reports the results of a pilot study and tests the industry's appetite for adopting such a pedagogical approach to information exchange.

Method

As a starting point an extensive literature review was carried out with particular attention drawn to the various BIM Manual / BIM Guideline documents now emerging around the world through organisations such as the buildingSMART Alliance. Information is not lacking, however, practical experience in moving forward with BIM beyond office boundaries in Sweden still is in its infancy.

Following an investigation of existing literature and other published guidelines, the BIM PEPG was identified to provide a suitable supporting platform to launch a study focused on shaping an overview of the use and benefits of BIM on a typical residential case construction project and exercising a method of reaching a common agreement with regards to information exchange and extent of implementation.

A pilot project was launched, establishing a collaboration between academic experts at Lund University and industry through White Architects in Malmö. The purpose was to initiate a strategic study centring on the question of BIM implementation in construction, and specifically information exchange, with an aim to solve some of the structural and organisational issues associated with this new working method in Sweden.

Common goals were to establish a documentable and transferable method of overcoming difficulties in implementing BIM focusing on practical solutions to advance information exchange. A series of workshops were carried out in connecting with applying the BIM PEPG to a case project: Gyllins Trädgård in Malmö. The case project provided a real-world setting for the study, facilitating a grounded source of valid data collection.

Through the enquiries required to develop and define the BIM implementation processes described in the BIM PEPG, valuable data was collected, organised and analysed. The guide's planning procedures formed the basis of the dialog with White Architects in Malmö and enabled a pedagogical and thorough approach whereby data has been collected for the purposes of analysis and potential system optimisation for future projects.

Implementation

The BIM PEPG provided the basis for initial dialog and facilitated a method to responding to the information exchange issues outlined in the problem statement. It is well aligned with the scope and purpose of this study and enables teams to focus on defining the necessary information exchanges through a step-by-step planning procedure as follows:

- ✦ Define project and team value through the identification of BIM goals and uses.
- ✦ Develop a process which includes tasks supported by BIM along with information exchanges.
- ✦ Develop the information content, level of detail and responsible party for each exchange.

Step 1: Agree BIM Goals

Here the design team identified a number of key *BIM Goals*, each allocated with a priority rating and a potential *BIM Use* (See Figure 21). It is essential to identify the specific goals that will provide incentive for implementing BIM on a project basis, with consideration to potential benefits, team competencies and technical resources.

Priority (1-3)	Goal Description	Potential BIM Uses
1-Most Important	Value added objectives	
1	Reduce design failures	3D Design Coordination, Quantity Scheduling
3	Optimise building rational	Phase Planning (4D Modelling), Site Utilization Planning
1	Establish early control of areas / spaces / relationships	Area Scheduling, 3D Design Coordination
3	Manage design / construction information better	Design Authoring
3	Letting out information	Area Scheduling



BIM Goals Worksheet (After Anumba et al, 2010)

Figure 21: Extract from: BIM Goals Worksheet – Gyllins Trädgård, Malmö

By identifying such goals the design team made a first step in planning for a level of BIM implementation. The definition of project team BIM goals allows individuals to understand each other's contribution and outlines the motivations behind the forthcoming information exchanges.

Next, the identified BIM goals are translated into actual BIM uses. The relationship between BIM goals and uses is interpretive and in which a common understanding and agreement is reached through early collaboration and planning.

BIM Anatomy: An investigation into implementation prerequisites

BIM Use*	Value to Project	Responsible Party	Value to Resp Party	Capability Rating			Additional Resources / Competencies Required to Implement	Notes	Proceed with Use
				Scale 1-3 (1 = Low)					
	High / Med / Low		High / Med / Low	Resources	Competency	Experience		YES / NO / MAYBE	
Digital Fabrication	Med	SE	Low	1	1	1	Roof trusses	Yes	
		MEP	Low	2	2	2	Ventilation ductwork / installation		
		C	High	2	2	2			
3D Design Coordination	High	A	High	3	3	2		Yes	
		MEP	High	3	3	2			
		SE	High	1	1	1	Training in Revit required	Revit coordination & 2d dwg	
Design Authoring	High	A	High	3	3	3		2D / 3D communication / info	
		MEP	High	3	2	2			
		SE	High	2	2	2			
Sustainability Evaluation	High	A	High	1	1	1	Training in IES VE required	Miljöbygghetprogram SYD	
		MEP	High	2	2	2			
		Owner	High	1	1	1		No	



BIM Uses Analysis Worksheet (After Anumba et al, 2010)

Figure 22: Extract from: BIM Use Analysis Worksheet – Gyllins Trädgård, Malmö

Through auditing a capability rating against each BIM use, responsible parties make an objective judgement with regards to their resources, competency and experience - in other words their professional ability to carry through the BIM use (see Figure 22). Together these parameters lead project teams to decide whether or not to proceed with a proposed BIM use. In the case of Gyllins Trädgård, however, a number of aspirational BIM uses were pursued to test results against traditional methods.

Step 2: Design BIM Project Execution Process

Once the team has identified the specific BIM Uses, a process mapping procedure for planning the BIM implementation can be performed. Initially, a high level map showing the sequencing and interaction between the primary BIM Uses on the project is developed. This allows all team members to clearly understand how their work processes interact with the processes performed by other team members. First the high level (Level 1) map is developed (see Figure 23), then more detailed process maps can be added by the team members responsible for each detailed BIM use. The high level map shows how the BIM authoring, energy modelling, and cost estimating, are sequenced and interrelated. The secondary detailed maps records the detailed processes that will be performed by an organisation or in some cases several organisations, such as the energy modelling.

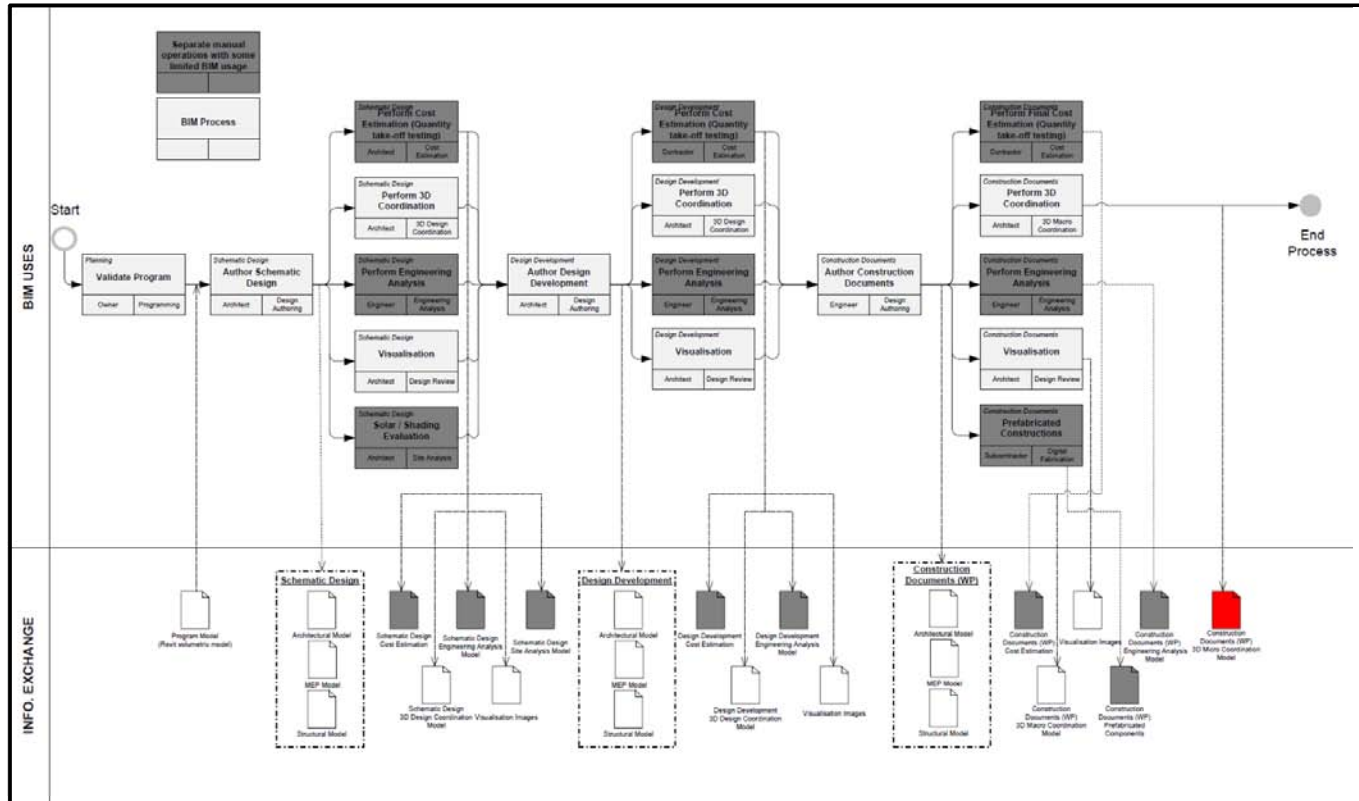
Engaging the design team in this process goes some way to determining the 'who' and 'when' questions previously cited.

Step 3: Develop Information Exchange Requirements

Once the appropriate process maps have been developed, the information exchanges which occur between the project participants can be identified. It is important for the team members, in particular the author and receiver for each information exchange transaction, to understand the information content.

This information content for the exchange is defined in the *Information Exchange* table (see Figure 24). Here, consultants develop a chart mapping information exchange content, level of detail and responsible party for each exchange. This procedure identifies the vital information required to implement each BIM Use as defined previously.

BIM Anatomy: An investigation into implementation prerequisites



BIM Information Exchange Worksheet (After Anumba et al, 2010)

Figure 23: BIM Execution Process Map (Level 1) - Gyllins Trädgård, Malmö

BIM Anatomy: An investigation into implementation prerequisites

BIM Use Title	Design Authoring (Schematic Design)			Cost Estimation			3D Coordination			Design Reviews			Energy Analysis		
Project Phase	Design			Design			Design			Design Reviews			Design		
Time of Exchange (SD, DD, CD, Construction)	SD			SD			SD			SD			SD		
Responsible Party (Information Receiver)	A, SE, MEP			Cost Consultant			A, SE, MEP			A, SE, MEP			Energy Consultant		
Receiver File Format	Revit *.rvt Acad *.dwg						Navisworks *.nwd			Navisworks *.nwd			Acad *.dwg		
Application & Version	Revit V.10, Acad, MagiCad						Navisworks V.10			Navisworks, PowerP			VIP +		
Model Element Breakdown	Info	Resp Party	Additional Information	Info	Resp Party	Notes	Info	Resp Party	Notes	Info	Resp Party	Notes	Info	Resp Party	Additional Information
A SUBSTRUCTURE															
Foundations															
Standard Foundations	A	A/SE		A	A/SE		A	A/SE		A	A/SE				
Special Foundations	A	A/SE		A	A/SE		A	A/SE		A	A/SE				
Slab on Grade	A	A/SE		A	A/SE		A	A/SE		A	A/SE				
Basement Construction															
Basement Excavation	A	A/SE		A	A/SE		A	A/SE		A	A/SE				
Basement Walls	A	A/SE		A	A/SE		A	A/SE		A	A/SE				
B SHELL															
Superstructure															
Floor Construction	A	A		A	A		A	A		A	A		A	A	
Roof Construction	A	A		A	A		A	A		A	A		A	A	
Exterior Enclosure															
Exterior Walls	A	A		A	A		A	A		A	A		A	A	
Exterior Windows	A	A		A	A		A	A		A	A		A	A	
Exterior Doors	A	A		A	A		A	A		A	A		A	A	
Roofing															
Roof Coverings	A	A		A	A		A	A		A	A		A	A	
Roof Openings	A	A		A	A		A	A		A	A		A	A	



BIM Execution Process Map (Level 1) (After Anumba et al, 2010)

Figure 24: Extract from: BIM Information Exchange Worksheet - Gyllins Trädgård, Malmö

Key Findings

The key findings from this pilot study are summarised below as follows:

- ✦ The BIM PEPG presents a valuable method of determining important prerequisites for effective BIM implementation.
- ✦ The procedures enable team members to gain a strategic insight into the who?- what?- when?- how?- questions relating to information exchange that BH90 fails to capture.
- ✦ The process facilitates a rational of continuous improvement by enabling teams to identify areas where processes are sub-optimal and offers flexible direction to achieve BIM integration.
- ✦ By testing this implementation model in practice, it has enabled a level confirmation of its suitability to complement BH90 at a strategic level.
- ✦ The study confirms that a pedagogical BIM implementation guide has useful practical application in the Swedish DCO sector (at least from a consultant perspective).
- ✦ The study revealed difficulties exist in obtaining a consistent level of information across all disciplines within the same timeframe. This issue is taken up in Paper 2.
- ✦ The BIM PEPG enabled members to focus on perfecting the areas where BIM implementation is successful and where results are trusted.
- ✦ Further local refinement might identify the conditions necessary for success and the barriers which might limit a full implementation.
- ✦ Difficulties were revealed in aligning consultant's information exchange content expectations – time wasted on file clean-up. This issue is taken up in Paper 2.

- ✦ The BIM PEPG helped improve clarity of purpose regarding information needs set against specific BIM Uses, allowing consultants to focus on generating the information need in a systematic way.
- ✦ One interesting finding was that the BIM PEPG could not be properly implemented as it was simply a practical impossibility to have the whole team present to contribute to the process. This issue is taken up in Paper 3.
- ✦ Whilst the plan was met with a certain level of enthusiasm amongst participants, it was time demanding. Consultants need to be prepared to allocate time at the early stages for BIM planning activities.
- ✦ The presentation of possible BIM-Uses helped the consultant team identify their strengths and even offered inspiration as to what other BIM services that they could offer.

The process and components involved in the BIM PEPG are closely tied to the development of the *Information Delivery Manual (IDM)* and *Model View Definition (MVD)* in which exactly

which information is to be exchanged in each exchange scenario, and which parts of the IFC specification are used, is specified. By encouraging organisations to take part in planning for information exchange, and articulating such parameters in a coherent and pedagogical way, it enables awareness of requirements and provides participants with something of a prelude to the IDM – a key part of buildingSMART’s folio of standards.

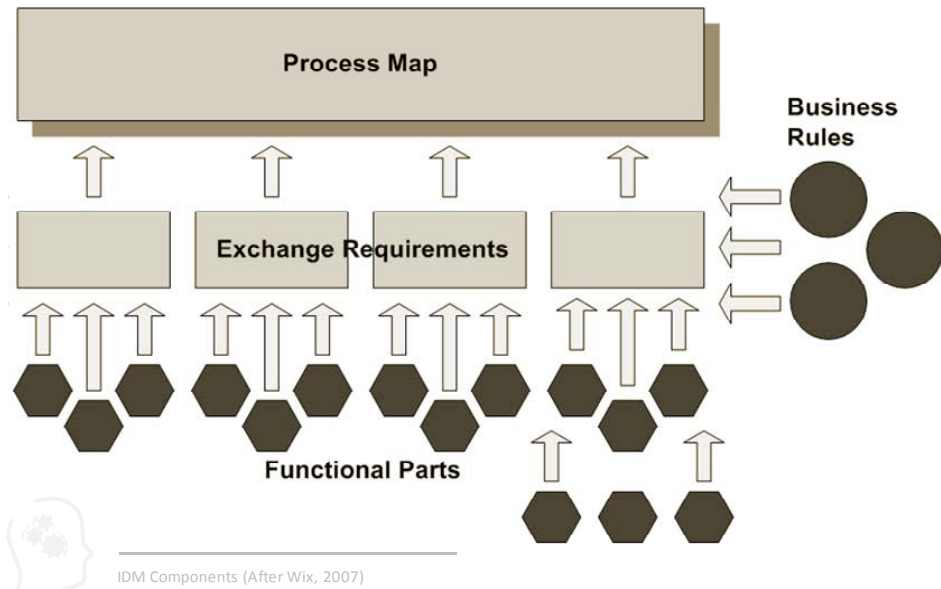


Figure 25: IDM Components (After Wix, 2007)

The conclusion of this preliminary study naturally leads to the development of a more extensive study of information deliveries and standardisation needs relating to the use BIM and implementation planning centred around the idea of BIM Uses.

4.1.2 Paper II: A BIM-Info Delivery Protocol

Introduction

The context of the study is directed toward the Swedish DCO sector where the concept of *Leveransspecifikationer* (Delivery Specifications) is suggested within the national guidelines for digital information management: BH90.⁸⁶ These guidelines recommend the use of

⁸⁶ SI, Swedish Standards Institute (2008), *Bygghandlingar 90 : byggsektorns rekommendationer för redovisning av byggprojekt*. D. 8, Digitala leveranser för bygg och förvaltning, Stockholm : SIS Förlag AB.

delivery specifications to accompany exchanges in digital information at all stages of the design, construct and operate process. However, there is a lack of concrete advice on how to develop information delivery specifications for defining and recording BIM-Info content in connection to or supporting a project based strategic BIM Implementation Plan and there is hitherto an absence of developed examples of delivery specifications to accompany national standards.

Purpose

Whilst organisations such as the buildingSMART Alliance are investing considerable resources towards developing AEC industry standardisation in information exchanges, until understanding, control and trust can be gained in the use of IFC, IDM and MVD by DCO participants, a simpler system of describing information content requirements is essential to BIM implementation today on a consultant practice level.

Without a straightforward way of creating project specific IDM's, a clear understanding of the content of MVD's, and the ability to control information flow through such methods, trust will may wither and die. Thus the driver for this study: the urgent need for a simple, user-friendly method of describing, in a commonly understood way, information deliverables.

Method

Two case projects were identified. The first to enable a closer examination of the issues involved. The second to test a protocol proposal that enables identification and categorization of the building parts and level of detail required to be authored against specific BIM-Uses, together with the exchanges that need to take place.

Primarily data was collected through observations at design coordination workshops associated with case #1. Secondary data reflecting the results from an experimental coordination model (case #2) enabled collection of further, more detailed information, eliminating unwanted variables, and facilitating a more precise examination of objects and properties required for 3D Design Coordination through the design phase.

Hypothesis

Perhaps a simpler method of generating IDM's and MVD's using commonly available tools within organisations would have greater mileage than those developed by external agents. Here it is conjectured that, as a valid alternative, BIM-Info Deliveries developed by design consultants for design consultants may offer the control, confidence and simplicity necessary for effective information exchange success.

In order for industry professionals to get the best out of BIM tools and work efficiently, one needs a big picture understanding of information need, honing individual tools and processes towards greater efficiency and certainty. Key to doing this is a thorough documentation of one's own business processes – use of a *BIM-Info Deliveries Protocol* as part of a *BIM-Implementation Plan* may offer an immediate and tangible solution.

Implementation

As a valid alternative to the IDM's being developed by the buildingSMART Alliance and others, the goal of this study is to offer a simple method of defining, on a project basis, information deliveries for specific BIM Uses.

It has been suggested that if the industry is to move forward with BIM implementation, firms must focus on perfecting what they can deliver.⁸⁷ Initially this means reaching for the low hanging fruit such as *3D Design Coordination* (through use of collision control tools) and early *Energy Analysis* (through use of built-in or associated energy simulation tools).

Both these BIM uses instantly add value to the DCO process and product and can be considered strategic, straightforward targets for consultant organisations to master in an efficient manner. What is problematic, however, is for team members to arrive at the same place at the same time with regards to BIM-Info quality and completeness. This is particularly critical in the context of the successful execution of various BIM-Uses including 3D Design Coordination. Project direction and information flow often meanders left and right of an efficient path resulting in frustration, loss of momentum behind value-adding processes, and often considerable time wasted.

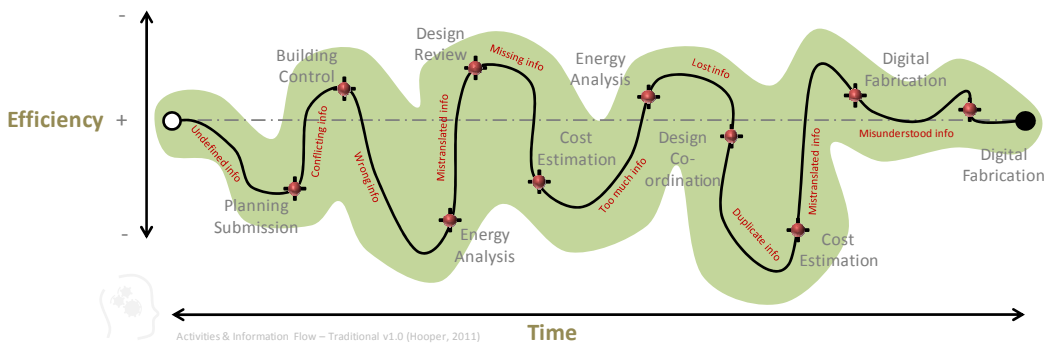


Figure 26: Activities & Information Flow – Traditional

⁸⁷ Jernigan, F. (2008), *BIG BIM little bim: The Practical Approach to Building Information Modeling-integrated Practice Done the Right Way!*, 2 edition, Salisbury: 4 Site Press.

Emerging from the observations and results revealed through discussions and experiments, the BIM-Info Delivery Protocol (IDP) is presented below as a sequence of pedagogical steps designed to respond to the research questions.

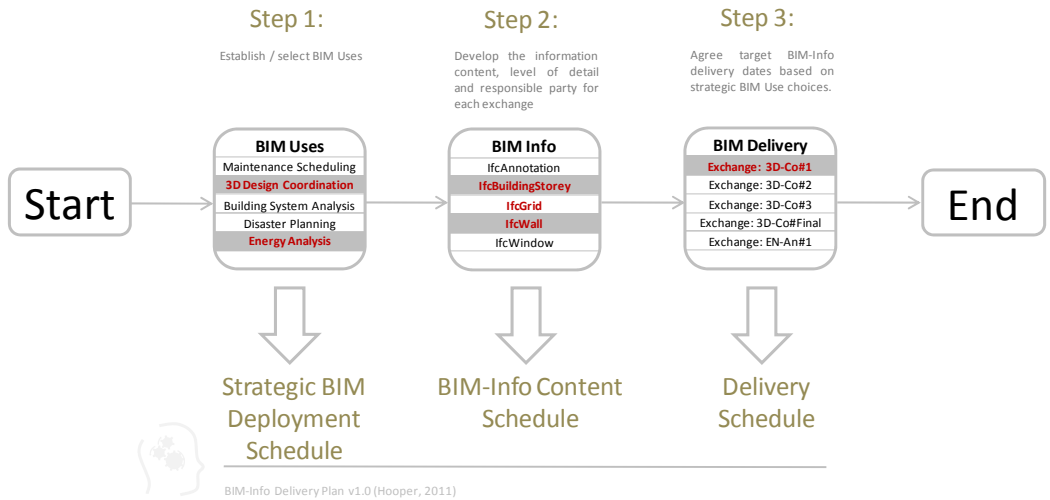


Figure 27: BIM-Info Delivery Protocol

Step 1: BIM-Uses

The buildingSMART Alliance's *Building Information Modelling Execution Planning Guide* suggests a list of 25 typical BIM Uses including of course 3D Design Coordination and Energy Analysis. It naturally follows that teams must establish at the outset the strategic BIM-Uses they wish to deploy on a project specific basis.



Figure 28: Example BIM-Uses

The decision to implement a BIM-Use must be based on resources, competency and anticipated value to the project. Against each BIM-Use members should consider and articulate the timing of such activities through the BIM-Authoring stages to enable focus on imminent information demands and optimize information flow. The figure below illustrates how this might be articulated whilst enabling efficient implementation.

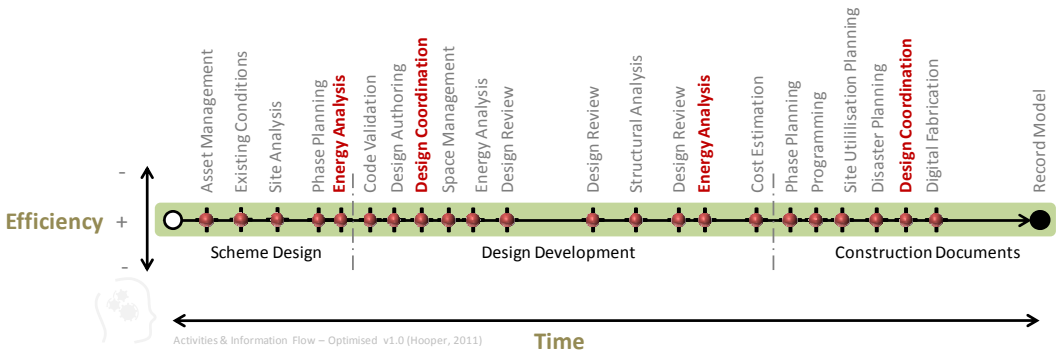


Figure 29: Activities & Information Flow – Optimised

Often overlooked, there is common business sense to the idea that, if certain design information can be supplied at right time then its value to the project can be optimized. BIM-Uses should be selected for the right reasons – as drivers to the process and to help provide the data to support strategic decisions along the way.

Step 2: BIM-Info

Here a definition of the model information content for strategic BIM implementation is articulated through scheduling the key objects with associated level of detail and responsible party. In this instance a BIM-Info Delivery Specification (IDS) template has been developed to express the information content and exchanges necessary to carry out and efficiently implement BIM-Use: 3D-Co (3D Design Coordination).

The main tools used to develop this schedule were Autodesk Revit Architecture together with Microsoft Excel. An important aspect of this study and resultant product is that by utilising industry standard tools and readily understood categories and classifications, consultants can maintain control of model content definitions and thereby build and retain trust in the exchange processes they create.

BIM Anatomy: An investigation into implementation prerequisites

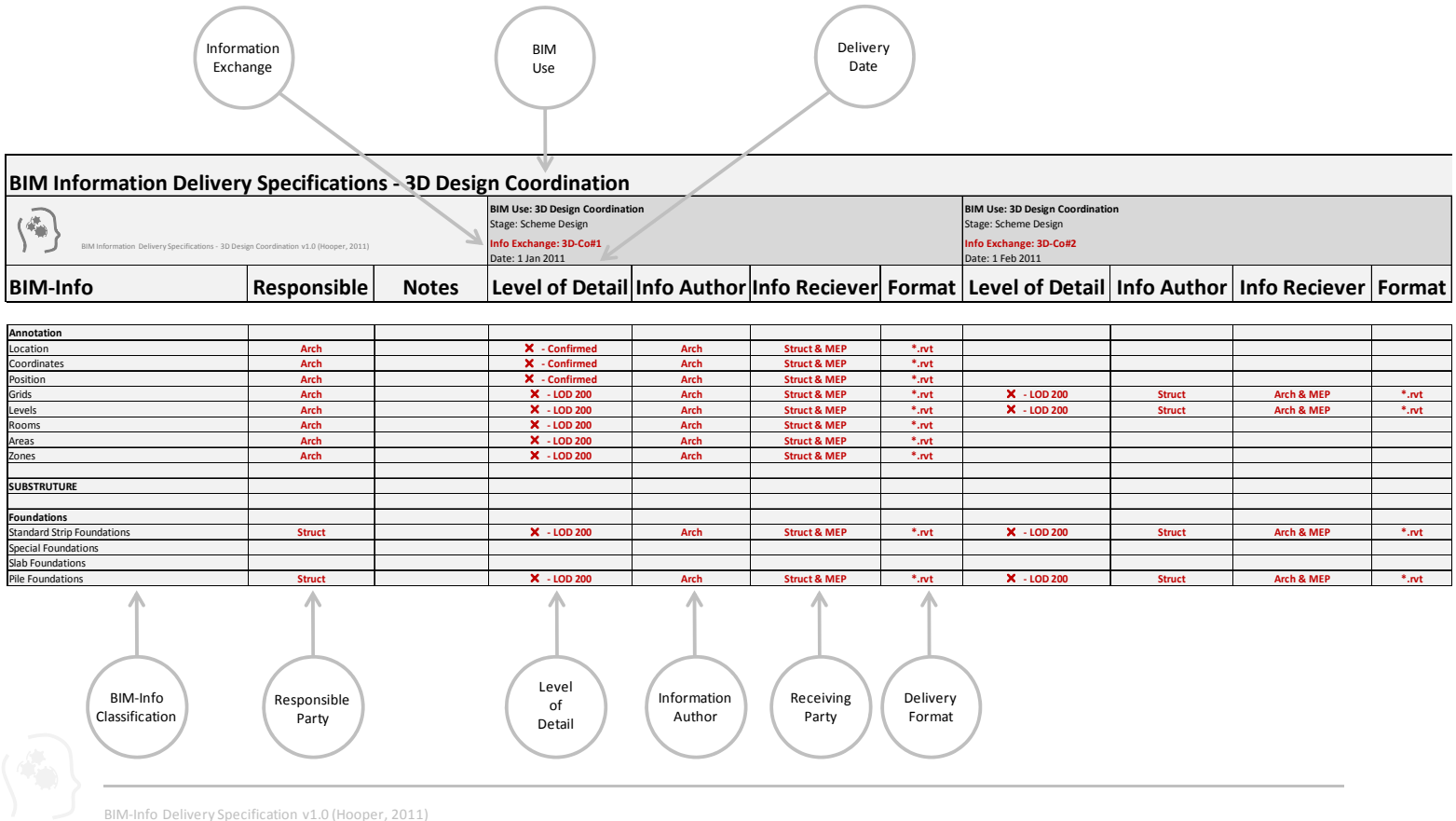


Figure 30: BIM Information Delivery Specification

Step 3: BIM-Delivery

Registry of BIM-Info exchanges can be readily recorded and communicated through project networks in accordance with the delivery schedule. However, often neglected is a sub-process of quality control. This is necessary more than ever – not least to demonstrate due diligence – but to ensure the content of BIM-Info Deliveries match with the general expectations of the project team as articulated in the BIM-Info Delivery Specification schedule. This process is essential to eliminate rework for receivers and puts the onus on the supplier to ensure the contents is what it says it is.

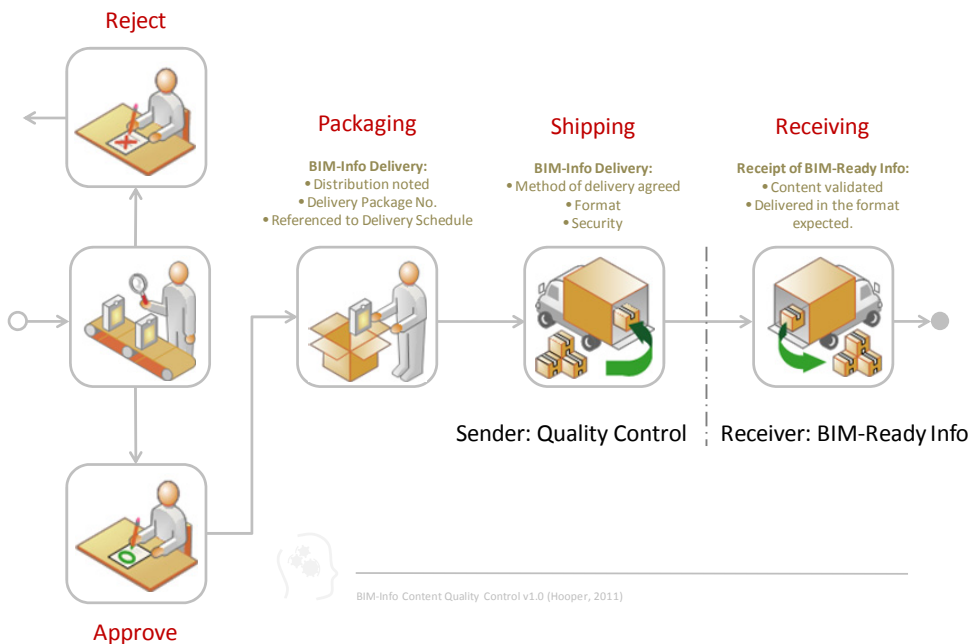


Figure 31: BIM-Info Content Quality Control Measures

Key Findings

The key findings to this study can be summarised as follows.

The key deliverable of this study is the BIM-Info Delivery Protocol (IDP) which attempts to:

- ✦ Enable BIM-Info to be defined and more efficient produced and shared through use of straight-forward and easy to use tools.
- ✦ Be a practical working method of aligning consultant BIM-Info delivery expectations.
- ✦ Represent a development of the concept behind BH90's *Leveransspecifikationer*.

- ✦ Enable users to methodically articulate and record information flow and priorities in standard way.
- ✦ Be a tool to understanding each other's information needs.
- ✦ Provide scope to reduce the risk for misunderstanding, waste and re-work.
- ✦ Enhance the quality of the product and help safeguard the success of project.
- ✦ Facilitate a clear and commonly understood picture of the BIM-Info Deliveries.
- ✦ Offer a clear and tangible solution to help consultant disciplines manage BIM-Info.
- ✦ Enables teams to add maximum value to the project.
- ✦ Take the guesswork out of digital exchange.

Digital exchanges are facilitated by the BIM-Info Delivery Specification (IDS), where the key parameters are: *BIM Use, Project Stage, Info Exchange (number), Delivery Date, Classification of Building Objects, Responsible Party* for the information, *Level of Detail, Information Author, Information Receiver, Format* of data.

The timing and content of BIM authorship is critical. By articulating planned BIM-Uses, the necessary BIM-Info needed to carry out these Uses together with target BIM-Delivery dates; project teams can more readily focus on the strategic task in hand and help each other to deliver the intended result in an efficient manner.

The BIM-Info Delivery Protocol (IDP) is a compelling tool for use in the evolving world of virtual design and construction teams and can be used as a basis for a BIM Management Plan. However, industry reference-group feedback has suggested a number of limiting factors including that *“it would be an additional burden, indeed laborious, to fill out the IDS when projects are already on a tight time schedule and budget. If teams cannot directly see the positive effects of using such a protocol, it would be difficult to achieve widespread uptake.”*⁸⁸ This protocol represents a tool for improvement, a first step could be to first record one's own strategic information requirements, recognition of this together with patience may prove to be prerequisites.

4.1.3 Paper III: Contractual Hindrances to BIM Collaboration

Introduction

Today DCO organisations are starting to leverage the benefits of implementing BIM on construction projects, however, to move beyond organisational optimisation (see Figure 9),

⁸⁸ Feedback from presentation of results to industry experts.

one of the challenges facing sector players is to overcome contractual hindrances to BIM collaboration.

BIM implies new workflows where sharing of data-rich models is part-in-parcel of the design development process and downstream users of digital information, authored by design consultants, can be made use of with confidence and assurance. Today only paper drawings have any contractual status; second and third party participants use digital information at their own risk.⁸⁹

Participants, particularly design consultants must be equipped with adequate contractual provisions for sharing, exchanging and using digital information, not only in order to avoid disputes (which are in any case rare) but to enable and support BIM collaboration processes and certainty beyond organisational boundaries.

Purpose

Collaboration is at the core of the use of BIM technology across sector disciplines and through facility life cycles. This study attempts to identify and address a number of contractual hindrances to meaningful collaboration in connection with the deployment of BIM in Sweden and furthermore suggest the necessary components to help overcome collaboration difficulties.

Through a review of existing documents, industry interviews, and an investigation of how collaboration difficulties have been overcome elsewhere in connection with the use of BIM technology, this study aims to articulate possible suitable measures to improve project outcomes by means of organisational shifts (to optimise scope of key player buy-in) and strategic BIM-Decision support instruments.

If validated through trial, standard BIM collaboration support mechanisms could be implemented as branch standard through appended contract clauses.

Method

The main findings on contractual hindrances to BIM collaboration build on an critical analysis of key documents including ABK 09,⁹⁰ AB 04,⁹¹ ABT 06,⁹² ADL 2010,⁹³ AIA's Document E202-

⁸⁹ Edgar, J-O. (2008) ByggIndustrin – Issue 34 – *Entreprenörer bygger på egen risk* – Nov 2011.

⁹⁰ BKK (2009) *Allmänna Bestämmelser ABK 09: För Konsultuppdrag inom Arkitekt- och Ingenjörsvksamhet*, Svenskbyggtjänst, Stockholm.

⁹¹ BKK (2006) *Allmänna Bestämmelser AB 04: För Byggnads-, Anläggnings- och Installationsentreprenader*, Svenskbyggtjänst, Stockholm.

2008,⁹⁴ AIA's IPD Guide,⁹⁵ and BIM PEPG,⁹⁶ then applies Focus Group Interviews (FGI's) as secondary research method of data collection to identify where the industry perceive hindrances exist and assess the level of concern.

The data gathered is largely qualitative, and has been analysed to discover and highlight the key components that influence the particular phenomena under study and enable a clearer understanding of both the existing contractual hindrances to BIM collaboration in Sweden and what concepts may be relevant to address these hindrances.

Key Findings

A consensus of opinion revealed itself in a number of areas:

- ✦ Low levels of support for BIM processes within existing contractual forms of agreement.
- ✦ Many administrative and psychological obstacles to collaboration and BIM processes exist which are interlinked.
- ✦ What is hindering is perhaps not what is there but what is missing.
- ✦ There is a lack of standardised BIM supporting documents in general.
- ✦ There is significant scope to standardise a number of key BIM supporting concepts and make available as branch standards.
- ✦ Individual organisations are developing their own internal BIM-Manuals (with the primary objective to optimise in-house processes) which although are attempting to bridge existing deficiencies in guidelines and protocols, are being developed and implemented in an ad-hoc way contributing to industry fragmentation.

Regarding the proposition presented through Figure 33 (below): Contract Documents – The necessary parts for BIM-Projects:

- ✦ *Level of Detail Schedule at each Stage* – was something that all respondents thought would be useful to aid and support collaboration. Currently this is missing and no comprehensive standard method of presenting this information as part of contract documents exists in Sweden.

⁹² BKK (2004) *Allmänna Bestämmelser ABT 06: För Totalentreprenader Avseende Byggnads-, Anläggnings- och Installationsarbeten*, Svenskbygg tjänst, Stockholm.

⁹³ Blom, H. (2010) *Avtal för Digitala Leveranser*, OpenBIM, Stockholm.

⁹⁴ AIA (2008) *AIA Document E202-2008: Building Information Modeling Protocol Exhibit*, AIA and AIA California Council, California, USA.

⁹⁵ AIA (2007) *Integrated Project Delivery: A Guide*, Version 1, AIA and AIA California Council, California, USA.

⁹⁶ Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2009), *Building Information Modelling Project Execution Planning Guide*, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

- ✦ Many questions remain over the responsibility for the correctness of digital information. For this reason amongst others, a standard form of *Object Author Matrix* was considered of value in conjunction with an information approval system.
- ✦ Whilst a number of internal BIM-Plans exist (taking various forms) a standard project specific BIM-Plan with an objective to align to whole-team BIM-Goals was recognised to be of benefit.

The augmented diagram below summaries the substance of the respondents' reactions to the hypothesis chart. It suggests that a core of interconnected supporting mechanisms are desirable and have potential to become branch standard. These components include:

- ✦ A BIM-Plan (including identification of common project goals, BIM-Uses etc)
- ✦ A BIM Delivery Schedule
- ✦ A BIM Authorised Uses Schedule
- ✦ A Level of Detail at Schedule at each Project Stage
- ✦ An Object Author Matrix

Scepticism prevailed regarding the relevance of an *Authorised Uses Schedule* (documenting how the recipient of a model may use the data) – since today models are generally only issued *for information only*, and for this reason the author sees no reason to regulate the recipient's use of it. But a model can potentially be used for a raft of different uses (costing, scheduling, performance simulation, code checking, and visualization, to name just a few), it seems obvious that the author of the model should define the suitability of the model for a particular use.

In order to appraise factors hindering collaboration, it was thought necessary to permit consideration to a variety of different classifications of hinder in order to firstly, appreciate the interconnectiveness of hindrances generally and secondly, to tease-out those hindrances that may not be immediately obvious. The categories selected to chart known hinders include: contractual, technical, economic and other including those that could be deemed social and / or psychological. The table below (Figure 33) records and presents this aspect of the findings.

The table highlights a number of interconnected hindrances relating to standards, communication procedures and even BIM as socio-technical system which can be seen to support the main theories and reinforce the case for renewed contracts that better support BIM collaboration.

BIM Anatomy: An investigation into implementation prerequisites

Contractual	Technical	Economic	Other (eg social / psychological)
<p>eg Responsibility for correctness of data</p> <p>Common practice to deliver the BIM model as requested, but only take legal responsibility for extracted 2d paper documents.</p> <p>ABK 09: BIM model has no contractual status.</p> <p>Clarity of purpose (BIM-Uses) missing</p> <p>Lack of branch standard language in connection with BIM-Concepts</p> <p>Lack of branch standard method of defining and controlling BIM-Deliveries - ie: BIM-Delivery Schedule</p> <p>Lack of branch standard method of detailing and controlling responsibility for data - ie: Object Author Matrix</p> <p>Lack of branch standard method of developing a strategic BIM-Plan - ie: BIM-Goal, BIM-Uses, BIM-Info Exchanges</p> <p>Lack of branch standard method of describing expected level of detail at various project stages</p> <p>ABK 09: Consultants are still required to print out and send 2D paper drawings - it is these that have contractual status</p> <p>Lack of branch standard method of detailing authorised uses of BIM data</p> <p>ABK 09: Rätt till uppdragsresultatet - consultants often asked to waive rights</p>	<p>eg Interoperability</p> <p>Consultants must still provide 2d drawings (paper and / or pdf) of design information (in addition to the model)</p> <p>This requirement for double information hinders the demand for BIM.</p> <p>Still much repetition in data entry due to lack of information stewardship, reliability, chain of information responsibility.</p> <p>Knowledge about each others BIM-Information requirements</p> <p>Awareness amongst AEC participants for what information is relevant at what time for what purpose.</p> <p>Awareness for information levels and lack of common expectation of how LOD should develop through DCO phases.</p> <p>Lack of standard method to define status of model content and level of accuracy</p> <p>Lack of standard method of reviewing and approving model content.</p>	<p>eg Difficulties is realizing ROI</p> <p>Big financial investment for consultants both in equipment and training.</p> <p>Imbalanced investment v. economic benefit across sector</p> <p>Little scope to realize win-win initiatives</p> <p>Difficulties is distinguishing and defining the boundaries between company BIM business strategy, project based BIM-Strategy and national BIM-Strategy.</p> <p>Time & money catch 22 - when there is high economy and pressure in the industry there is not the time to spend in developing BIM expertise, when there is a depressed economy there isn't the money to invest in BIM.</p>	<p>eg Low client interest in BIM</p> <p>Traditional process mindset</p> <p>Resistance to change</p> <p>Fragmented industry compartments efficiency initiatives</p>



Factors Hindering BIM Collaboration v1.0 (Hooper, 2011)

Figure 33: Factors Hindering BIM Collaboration

Significant barriers to BIM collaboration exist in Sweden today. It is clear that there is considerable potential for improvement of construction project organisation, and contractual provisions in connection with the use of BIM technology and implementation methodologies. The standardisation of supporting mechanisms for strategic BIM collaboration may offer a solution to address a number of these barriers.

The results of this study conclude that in Sweden a certain consensus of opinion exists with regards to what are the most important components required to support BIM collaboration and what has the potential to become branch standard.

Today most construction contracts utilise a standard AB form as the basis for engagement. There is nothing to prevent project participants attaching custom-made clauses to supplement these existing contracts and Clients often do. Appending some form of standard BIM-Addendum containing all necessary key supporting concepts may offer a compelling platform for improved strategic BIM-Collaboration and could represent a first step towards a more integrated project delivery.

However, to address the secondary matters of mindset and project organisation (including timing and scope of appointments), a conscious move towards IPD may be necessary. (A separate investigation looking at articulating recommendations regarding the potential of IPD in Sweden has been initiated though SBUF and OpenBIM.)⁹⁷ There is a pressure on the industry to adapt contracts that properly facilitate in the increase in effort and collaboration during the early design phases and which permit contractor, specialist subcontractor and supplier input from the outset.

To summarize, this study reveals that a certain consensus was identified in the following areas:

- ✦ AB04 / ABT06 / ABK09 are very generally written with little reference to methods of BIM execution and / or collaboration.
- ✦ Whilst the content of AB06 / ABT06 / ABK09 generally appears not to specifically hinder BIM collaboration, they do not support the use of BIM either.
- ✦ Some other supporting BIM documentation, standards & BIM concepts are to be found in fragmented form within organisations' own 'BIM-Manuals'.
- ✦ The Totalentreprenad (A hybrid of the American *Turnkey* and UK *Design & Build* forms) form presents the best potential as a basis to move towards an integrated project.

⁹⁷ Qvarnström, G., Ask, A., Hooper, M. (2012) BIM och Avtalsformer - En jämförelse mellan befintliga avtalsformer och Integrated Project Delivery, IPD, SBUF-projekt med OpenBIM, Sweden.

- ✦ There is potential for 5 key elements of supporting documentation to become branch standard in Sweden, namely: *Project-based BIM-Plan*, *Object Author Matrix*, *Level of Detail Schedule at each Stage*, *BIM-Delivery Schedule*, and *BIM Authorised Uses Schedule*.

Furthermore:

- ✦ Contract types influence the extent to which AEC participants can collaborate. The AB family of contracts in Sweden offer little direct support for BIM collaboration and in this capacity can be considered a hinder. Supporting mechanisms are needed as a first incremental step towards IPD.
- ✦ Many hinders exist that are not only contractual but are related to the socio-technical system that the contract regulates.
- ✦ Whilst potential for greater branch fragmentation exists as a result of emerging discrete in-house BIM-Manuals, a number of key BIM collaboration supporting mechanisms (often taking different forms within in-house BIM-Manuals) have the potential to become branch standard.
- ✦ Contractors work from BIM data-models produced by consultants at their own risk. If something goes wrong neither the Architect nor Structural Engineers can be held responsible.
- ✦ A responsibility matrix should form part of the appointment documents to support the design and construction team's scope of work.
- ✦ *Approved for construction* 2d paper drawings are still the only legal construction documents.
- ✦ Downstream use of digital data must be considered intelligently by design authors at time of input to enable its use and avoid re-work. Authorised uses of the BIM data should be agreed and recorded with a view to maximise value and downstream use.
- ✦ BIM data-models are not *approved construction documents*. There are no contractual regulations for what legal status digital information has – this is a big risk for quality assurance.⁹⁸
- ✦ With BIM-Uses, responsibility levels and level of accuracy established; a clearer picture of the status of that digital information emerges.
- ✦ A broader range of supporting mechanisms is desirable, as branch standard, than those currently available within *Avtal för Digitala Leverancer 2010*. An updated version adopting key supporting mechanisms may go some way towards a more integrated project delivery.

⁹⁸ Edgar, J-O. (2008) ByggIndustrin – Issue 34 – *Entreprenörer bygger på egen risk* – Nov 2011 - <http://www.byggindustrin.com> – extracted November 2011.

- ✦ Various actors carry uncertainties and unnecessary risk associated with the use of digital information. A branch standard BIM-Addendum would seek to introduce greater clarity of purpose and enable project-based goals to be implemented.
- ✦ Some essential investment is required in simple, standard protocols and service schedules to better define BIM-deliverables, roles & responsibilities and desired outputs.

4.1.4 A Review of BIM-Guidelines: Content, Scope & Positioning

Introduction

A mini-study reporting on the content, scope and positioning of a selection of important and influential existing BIM standards and guidelines was carried out to support the main study and also serve as a contribution to the Interreg IVa Project⁹⁹. The documents reviewed include:

- ✦ NBIMS (US)
- ✦ BIM PEPG (US)
- ✦ AIA Document E202 – 2008 (US)
- ✦ NGDM (Aus)
- ✦ AEC BIM Standard (UK)
- ✦ Senate Properties BIM Requirements (FIN)
- ✦ Statsbygg BIM Manual (NO)
- ✦ BH 90 (Swe)
- ✦ BIPS (DK)

(See Appendix 2 for further description and commentary.)

⁹⁹ <http://www.interreg-oks.eu/se>



BIM Patterns: A spotlight on selected BIM Standards & Guidelines worldwide v1.0 (Hooper, 2011)

Figure 34: BIM Patterns: A spotlight on selected BIM Standards & Guidelines worldwide

Purpose

The purpose of this mini-study has been to:

- ✦ Create an inventory of existing BIM standards and guidelines.
- ✦ Categorize their key features.
- ✦ Identify any deficiency in the content, scope and positioning of the Swedish standards when compared with others.
- ✦ Present harmonisation / improvement proposition.

Method

Qualitative data was collected through a review of documents.

Key Findings

Through a review of documents, this mini-study attempts to map the positioning, content and scope of a selection of key and influential existing BIM standards and Guidelines in circulation today.

Positioning: The diagram below, a development of that from Gobar Adviseurs (2010)¹⁰⁰ indicates the positioning of these documents using *content and scope* together with *audience depth* metrics.

¹⁰⁰ Gobar Adviseurs (2010) An International Scope of BIM – A systematic review of BIM guideline documents, Gobar Adviseurs, Netherlands.

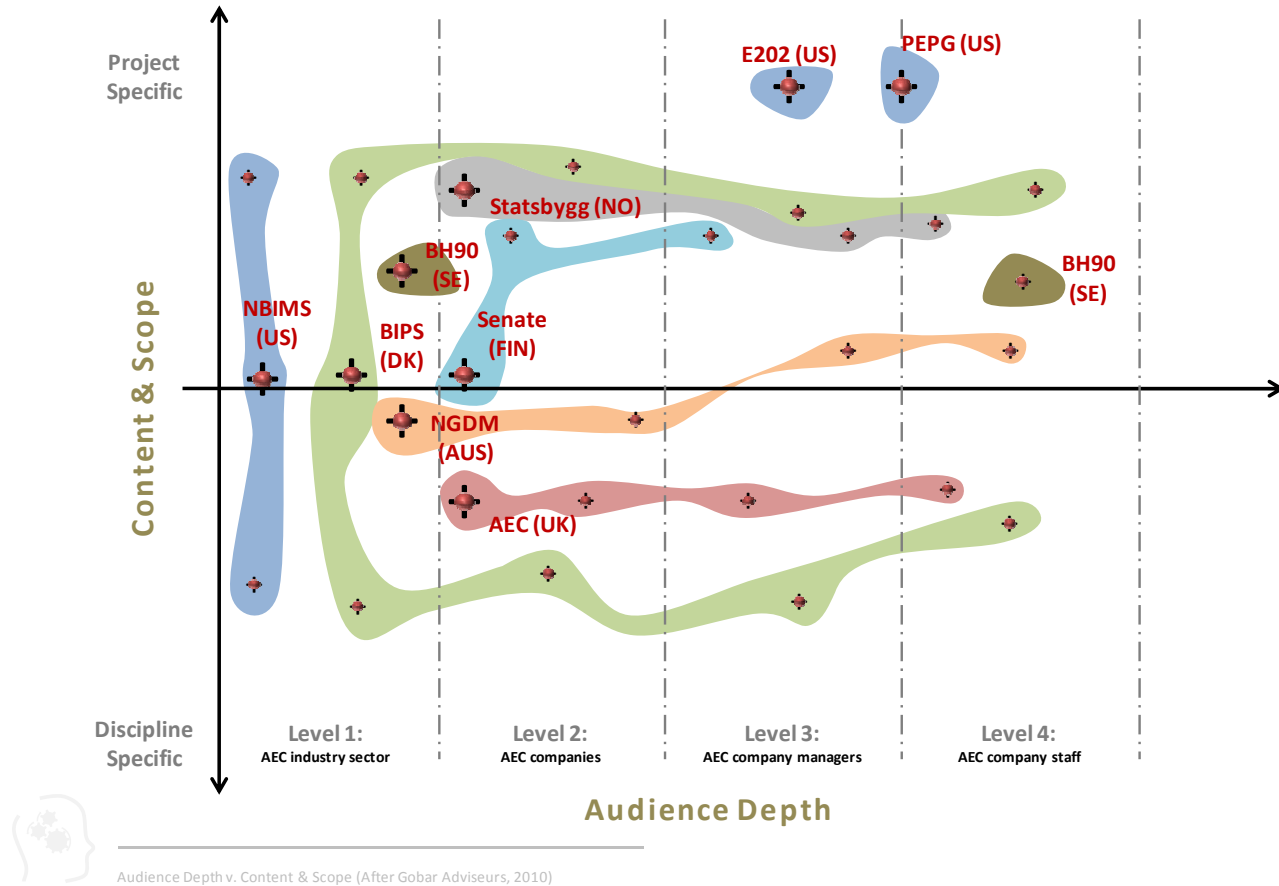
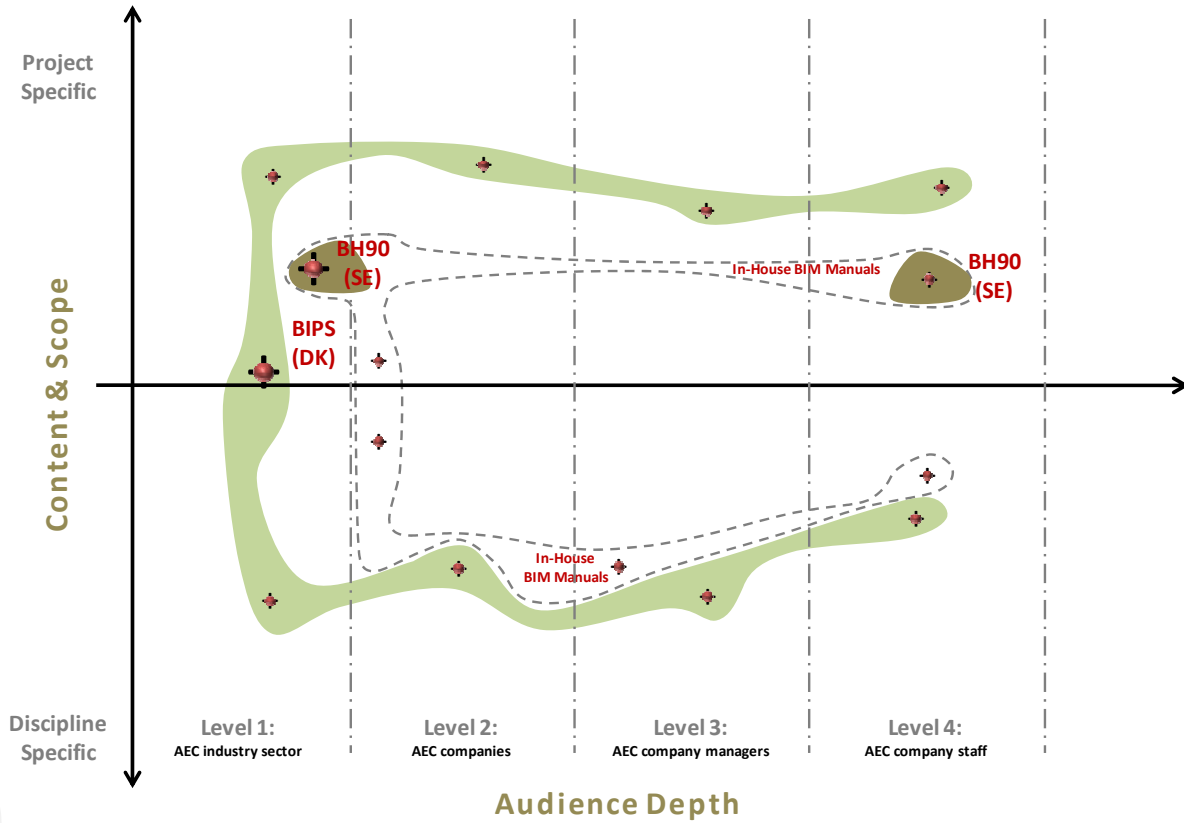


Figure 35: National BIM Guidelines Worldwide: Audience Depth v. Content & Scope

The diagram indicates that the Danish bips¹⁰¹ documents (multiple documents representing Denmark's national guidelines that include: *3D Working Methods*, *3D CAD Manual* and *Object Structures*) cover the most territory with regards content and scope, and address the deepest audience levels. Whilst *BH90*, representing administrative guidelines available in Sweden that are directed at design consultants, faring poorly regards both strategic support and audience depth.

However, there is an important twist to the tale. The above diagram is far from representative when considering Sweden's advanced use of BIM technology and processes. Notwithstanding the above, a key parameter has been neglected in this mapping exercise. The diagram below re-considers the relation between the far-reaching Danish documents and the Swedish BH90 with consideration to the *In-House BIM Manual* now in use throughout most large DCO organisations in Sweden.

¹⁰¹ Translated from Danish bips (byggeri - informationsteknologi - produktivitet – samarbejde) is an abbreviation of construction - information technology - productivity - collaboration.



DK / SE BIM Guidelines: Positioning v1.0 (Hooper, 2011)

Figure 36: DK / SE BIM Guidelines: Positioning

An artificial bridging of the gap in BIM guidance exists in Sweden through the development of In-house BIM-Manuals. Whilst this may solve one problem it can be seen to create another: there is a risk associated with the failure to have a national strategic approach to BIM, and that is the unnecessary and avoidable divergence in the strategic direction of BIM to the norm encountered on the international stage.

Furthermore, In-House manuals limit the spreading of knowledge and risk divergence or even contradiction in best practice procedures.

Content: From a selection of the main guideline documents available in Sweden, categorization can be assumed to identify the key characteristic of the document content.

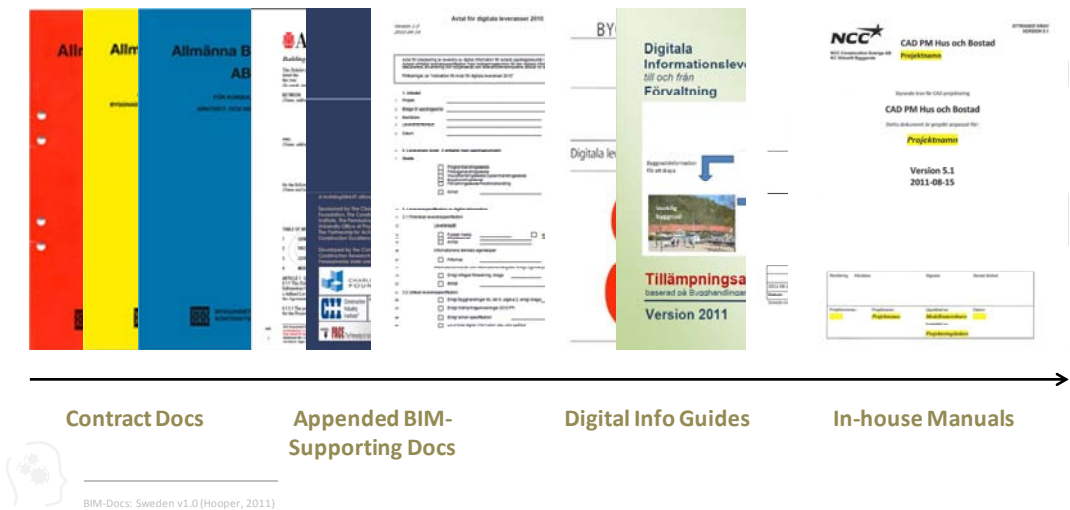


Figure 37: BIM-Docs: Sweden

Beyond this, one can map whether a document can be considered as an *administrative* guide or *strategic* guide. Here we can readily identify that there appears to be a deficiency in national guidelines purposed to support strategic BIM implementation decisions (see Figure 38).

Furthermore, it is suggested that a clear categorisation of documents may be of use to the industry to help understand their purpose. Whilst some administrative guidance to BIM methods and standards exist within BH90, it may not be clear within the industry as to where they reside within the bigger picture of BIM-Documents. Simultaneously it is critical that *administrative* and *strategic* documents correlate with each other to provide an integrated working platform.

The locally utilised abbreviated documents cited in the above diagram include:

ABK 09: [Allmänna bestämmelser för konsultuppdrag inom arkitekt- och ingenjörsvksamhet] Being the standard form of appointment for consultants (Architects & Engineers).

AB 04: [Allmänna bestämmelser för byggnads-, anläggnings-, och installationsentreprenader] Being the general conditions for procurement of construction contractors. AB 04 is produced by the Association of the Construction Contracts Committee (BKK).

ABT 06: [Allmänna bestämmelser för totalentreprenader avseende byggnads-, anläggnings- och installationsarbeten] Being the general provisions for Design & Build contracting for building, construction and installation and is intended for use in procurement and contract for works to be executed as a turnkey contract.

LOU: [Lag om Offentlig Upphandling] Being Sweden's law that regulates procurement undertaken by local authorities and other organisations which are financed with public money.

BSAB: [Byggandets Samordning AB] Being the common structure for information in the construction sector.

AMA: [Allmän material- och arbetsbeskrivning] Being a series of reference works that describe the requirements for materials, workmanship and finish results complete with templates for specification writing.

SB11: [CAD-lager. Rekommendationer för tillämpning av SS-ISO 13567 med BSAB 96 och Kodlista BH 90 för landskapsinformation.] Being national recommendations for CAD layering conventions. This document has recently been updated to include codes denoting the status of objects and includes an updated BSAB table for building components so it includes for infrastructure.

BH90: [Bygghandlingar 90 : byggsektorns rekommendationer för redovisning av byggprojekt] Being a series of documents (1-8) forming the construction industry's recommendations for the design of integrated and efficient construction documents.

Scope: When considering the scope of the above documents set against a background of the other international guidelines, a number of key BIM concepts and standards are prevalent. These are presented in diagram below. The diagram below also attempts to indicate the existing status or positioning of these common concepts in the context of BIM documents in Sweden. Here one can see that practically all of the key BIM concepts, processes and standards are hidden within organisations’ documents or in-house BIM manuals and very little in the way of branch standards exist.

Whilst it is logical that a number of key BIM concepts, processes and standards remain within the domain of the individual organisation - for amongst other things to create and maintain a competitive DCO market - it is equally valid that a number of concepts become, in the nations interest, branch standard.

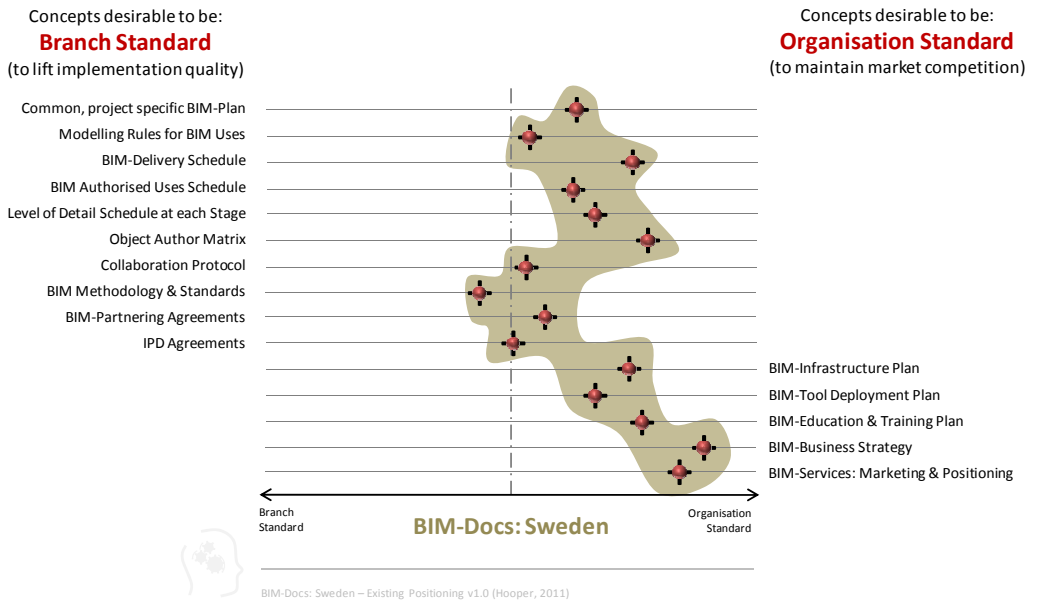


Figure 39: BIM-Docs: Sweden – Existing Positioning

A Repositioning Proposition: In order for Sweden to avoid the trap of divergent BIM strategy, it is suggested here that a number of key BIM concepts are transposed from *organisational standard* to *branch standard*. With consideration to what is happening elsewhere in the world, the diagram below illustrates an important repositioning proposition as an alternative to the status quo in Sweden.

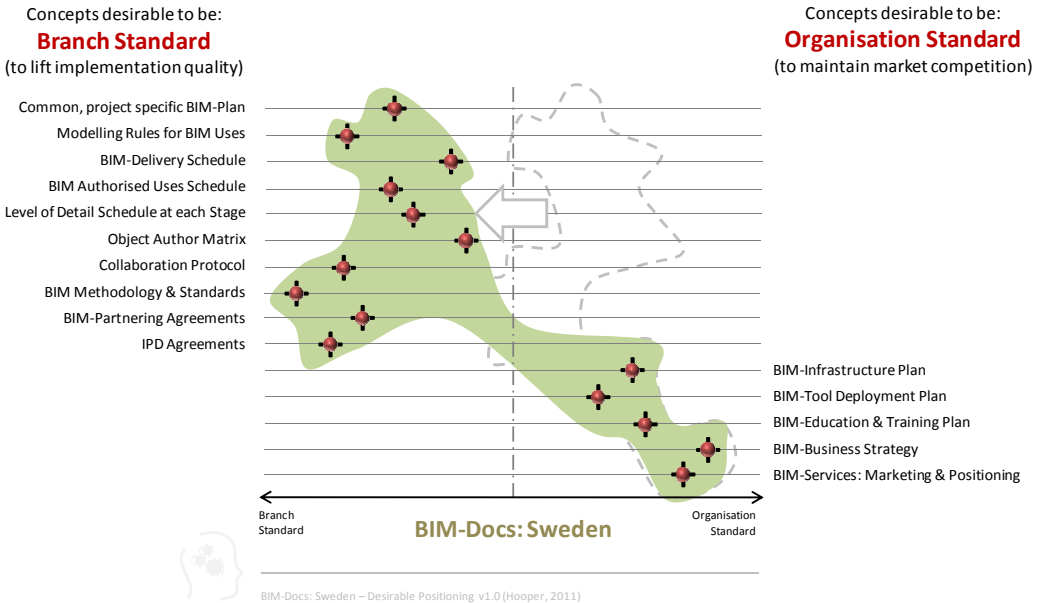


Figure 40: BIM-Docs: Sweden – Desirable Positioning

Summary

In the context of the main study and this mini-study’s contribution to the Interreg IVa Project, the main deducible points from this study are:

- ✦ Our Nordic neighbours have all had government mandates for at least 5 years.
- ✦ In Sweden the lack of state initiative has led to the industry taking their own organisational initiatives which in turn has led to a constellation of fragmented approaches.
- ✦ Fragmented approaches in the Swedish Construction Industry can lead to compromised cross-border competition and difficulties with harmonising cross-border standards (eg SE/DK).
- ✦ Organisational BIM guidelines (which attempt to bridge the gap in Swedish BIM standards) represent a hinder to national interests.
- ✦ There is a need for national standards together with a national vision for BIM.
- ✦ The Danish bips documents are an example of *de facto* standards developed by the private sector, Sweden could adopt a similar model through the Swedish Standards Institute (SIS).
- ✦ As with our Nordic neighbours, the lead / implementation driver, must come from the state, not from a few large construction companies with money to spend on innovation - as this only leads to organisational optimisation. BIM is bigger than that.

- ✦ Branch standards need to be developed to ensure an integrated approach is deployed. A body with objectivity, resource and clout is required to implement this through regulation & standards.

Furthermore:

- ✦ If one looks at other nations, on the one hand one has a government mandate and on the other a state driven demand for BIM together with state driven national standards.
- ✦ In Sweden development and implementation of BIM has been deliberately left to the AEC organisations.
- ✦ Challenges exists in aligning or harmonizing DK / SE guidelines as they have emerged from different drivers & initiatives:
 - ✦ BIM implementation & documentation in SE is largely market driven and the result of private initiatives. National guidelines are not specifically BIM orientated & don't have a broad audience.
 - ✦ DK guidelines are centrally driven and the result of public initiatives, have a broad audience, have the capacity to form the basis for a BIM implementation national standard.
- ✦ There are a number of key BIM supporting concepts emerging elsewhere that are hidden / missing from both SE & DK models.
- ✦ If one is to harmonize DK / SE working methodologies, one must look further than bips & BH90 as BH90 appears not to represent or reflect practice BIM adoption in Sweden.
- ✦ There is a tendency or sector culture to optimize at individual / organisational level only, not the entire process.
- ✦ In Sweden there is a need to:
 - ✦ Identify and shift those BIM supporting concepts, (hidden in organisation's BIM documents) to Branch Standards,
 - ✦ Define which BIM supporting concepts should be contract,
 - ✦ Identify BIM services market competition drivers.
- ✦ BIM-leadership: the role of the *project information officer* is emerging. Here a potential exists for Architects in Sweden to seize the opportunity to lead the BIM effort, raise their game and win back lost ground with BIM-leadership.
- ✦ National BIM strategy needs to be better documented & promoted.
- ✦ Comprehensive, multi-audience set of guideline documents to enable teams to learn, work better together, and make strategic project-based decisions.
- ✦ Government mandate required to strengthen legitimacy to the Swedish BIM-drive.

4.2 Assemblage of Key Findings & Results

An assembly of the key findings and results are presented below together with how they link with each other to form a plausible response to the main research questions.

A Pilot Project - Toward BIM integration - An analysis of design information exchange & coordination

Results from this initial pilot project, amongst other things, provided a broad insight into the typical status of BIM implementation in consultant practice and indication of where difficulties lie. It was apparent that consultants face a transition period between old practices and new together with the inherent risk of change. Pioneers however are beginning to utilise BIM tools more and are keen to exploit their potential either through client demand or in-house initiatives.

Under this study buildingSMART's BIM PEPG was tested alongside a typical residential construction project as a basis to articulate design information exchange requirement towards the creation of coordinated construction documents. The idea was to assess its suitability to fill a hypothetical gap in existing standards and provide a strategic complement to BH90 which provides guidance on administrative matters only.

The general findings in this respect were that the BIM PEPG offered decision and process support that hitherto had not been exercised. It helped team members determine and articulate to others *what* the BIM objectives are in terms of goals, BIM-Uses and necessary deployment of resources (technology and staff). *What* information may be required to be exchanged in relation to each BIM-Use, and against each of these, *who* will provide the information and *when* it is required. Collectively the plan's execution procedures enable teams to gain a strategic insight into the *who?*- *what?*- *when?*- *how?*- questions relating to information exchange that are otherwise only considered on an ad hoc and inefficient manner – contributing to re-work and waste.

Applied on a project basis, it provides teams with a standard method of determining important prerequisites for a more effective BIM implementation and, by facilitating a rational of continuous improvement through enabling teams to identify areas where processes are sub-optimal; it offers a meaningful and flexible direction to achieving a level of BIM integration.

The difficulties identified with the application of the BIM PEPG relate mostly to barriers to DCO team member participation, which in turn relates to the timings and scope of appointments and ultimately procurement method and contract.

Consultants know their routines of-by-heart but have been notoriously poor at recording them with a view to standardisation. One real benefit of applying a BIM execution plan is that it enables teams to see the potential of standardisation of process and identify areas in which routines (including information exchanges for specific BIM-Uses) could be standardised.

The pilot study confirmed that the gap in recognised BIM standards is real and that some form of BIM planning guidance specifically related to the strategic implementation of BIM on a project basis is needed.

A BIM-Info Delivery Protocol

The results from this study sought to establish a standard method of defining model information content for strategic BIM implementation based selected BIM-Uses. The output constitutes a BIM-Info Delivery Protocol (IDP) which is designed to enable an alignment of consultant information delivery expectations that was revealed to be a significant issue through early data collection sessions.

The pre-study corroborated that too much guess-work exists in information exchange and as such digital information deliveries could be better organised which may in turn reveal potential for standardisation. The study furthermore revealed:

- ✦ A lack of a common understanding of what each BIM-Use entails, not least in terms of BIM-Info deliverables.
- ✦ Time commitment in the early stages present difficulties and frustration, suggesting a resistance to change or flawed time planning.
- ✦ Difficulties exist for team members to arrive at the same place at the same time with regards BIM-Info quality and completeness.
- ✦ Quality Control and validation of delivered BIM-Info is often left to the receiver to sort out - leading to down time for file clean-ups, deletion of duplicate objects etc.
- ✦ Lack of trust in data integrity emerged. The completeness and accuracy of 3D models remain a major concern for the design team.

The emerging protocol attempts to combat these failures through a simple process where prerequisites for information exchange are articulated – enabling clear communication of what information needs to be delivered against each BIM-Use. It facilitates BIM-Info foresight, enabling teams to add maximum value to the project. In this respect it is noted that the timing and content of BIM authorship is critical. By articulating planned BIM-Uses, the necessary BIM-Info needed to carry out these Uses together with target BIM-Delivery dates; project teams can more readily focus on the strategic task in hand and help each other to deliver the intended result in an efficient manner. Resulting tool provides a means to

understanding each other's information needs, reducing the risk for misunderstandings, re-work, duplication and waste.

In conclusion the study's results represent a development of the concept *leveransspecifikationer* suggested within Bygghandlingar 90 but not substantiated. Further testing may enable judgements to be made regarding its suitability to support information exchanges through the entire DCO lifecycle but as a design information exchange tool it has demonstrated application.

Contractual Hindrances to BIM Collaboration

The focus of the main research required that questions related to procurement and contractual forms of agreement - and how they impact on DCO players' capacity to collaborate on BIM projects - had to be addressed.

Results revealed that whilst the standard forms of agreement (AB04, ABT 06 & ABK 09) presented little specific hindrance to BIM collaboration, they offered little support to the earlier collaboration processes necessary to enable a well-planned BIM project or attempts to move towards a more integrated (and mature) BIM implementation. Furthermore the procurement methods associated with said forms of contracts presented real barriers to BIM collaboration in terms of timings and scope of appointments.

To address these matters and a number of other key juridical difficulties the study, with cognisance to Avtal för Digitala Leveranser 2010 (ADL 10)¹⁰², considers a new BIM-Addendum to facilitate collaboration on matters of consequence relating to the use of BIM. A matrix of supporting mechanisms is established based on the AIA's Document E202-2008 Building Information Modeling Protocol Exhibit¹⁰³ and the need for renewed collaboration protocols built on model procedures.

The resultant BIM-Addendum comprises of 5 key components including: *Project-based BIM-Plan*, *Object Author Matrix*, *Level of Detail Schedule at each Stage*, *BIM-Delivery Schedule*, and *BIM Authorised Uses Schedule* together which form a set of decision support mechanisms which, if standardised, could better support BIM collaboration.

¹⁰² Blom, H. (2010) *Avtal för Digitala Leveranser*, OpenBIM, Stockholm.

¹⁰³ AIA (2008) *AIA Document E202-2008: Building Information Modeling Protocol Exhibit*, AIA and AIA California Council, California, USA.

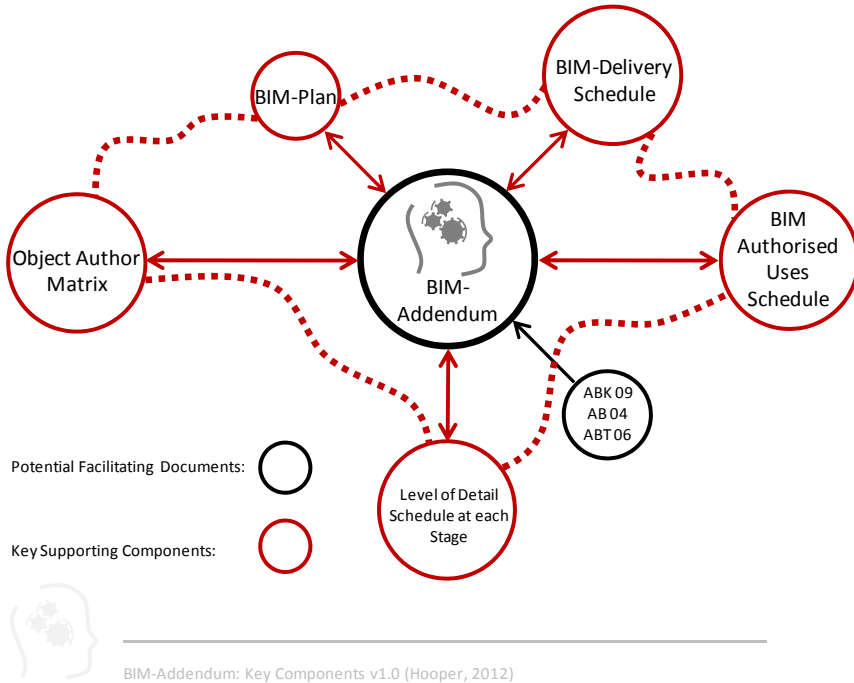


Figure 41: BIM-Addendum: Key Components

Project-based BIM-Plan: key to sorting out objectives, a strategic BIM-Plan (for example, buildingSMART’s BIM PEPG) should set out the project team’s BIM goals, uses, resources to be deployed, and planning for information exchanges through the project.

Object Author Matrix: enables teams to readily identify and be certain over *responsible party* for authoring and maintaining the correctness of *BIM content* and *status* of objects. Both variables are expected to change through the life of an object, a standard method is needed to record this to remove doubt and facilitate clarity.

Level of Detail Schedule at each Stage: intended to provide clients with an overview of the expected or attainable level of development at key project milestones, it can also be used to help align design consultants’ BIM authoring patterns and determine strategic points in time to deploy BIM-Uses, and nD applications.¹⁰⁴

BIM-Delivery Schedule: part of the *BIM-Plan*, related to the *information delivery specification* and herein included within the Information Delivery Protocol (IDP) detailed in Paper #2, this part enables standard articulation of what to deliver, when.

¹⁰⁴ nD: n-Dimensional where n is a number. Recognised examples are 3D Design Coordination, 4D Construction sequencing, 5D Cost Analysis, 6D Facilities Management, nD Energy Simulation.

BIM Authorised Uses Schedule: though a lack of consensus prevailed on this parameter, authorised use of digital information is a key matter on which earlier agreement can be advantageous. Here it is suggested that since a model can potentially be used for a raft of different uses (costing, scheduling, performance simulation, code checking, and visualization, to name just a few), it seems obvious that the author of the model should define the suitability of the model for a particular use.

Authorised uses of the BIM data should be agreed and recorded with a view to maximise value and downstream use.

A Review of BIM-Guidelines - Content Scope & Positioning

There are a number of important BIM guidelines – some constituting de facto standards – emerging around the world today. This mini-study, designed to provide the main study with an insight into the general status and positioning of existing guidelines, reveals some interesting results relating to content, scope and positioning of the Swedish construction documents guidelines (BH 90) set against a background of other national guidelines.

The study reveals gaps in the scope of BH 90 with reference to audience levels and attempts to articulate the bridging effect of in-house BIM Manuals which local organisations have been developing to address content deficiencies. Because many BIM practice procedures are either missing or hidden within in-house BIM manuals, with restricted audiences, it is highlighted that the nation runs a real risk of developing a *constellation of fragmented approaches*.

Those BIM decision support processes or mechanisms – such as strategic BIM planning, information delivery and collaboration support tools - that are desirable to be branch standard are expressed. The study then considers the drivers behind existing guidelines in the Nordics and even suggests that a Government mandate may be required to strengthen the legitimacy of the Swedish BIM-drive. It can be argued that as such, a lack of central government mandate may represent something of a constraint to implementation efforts and that national backbone to BIM guidelines can offer the legitimacy and propulsion necessary for consistent uptake of BIM standards.

4.3 The Need for an Effective Implementation Strategy (A BIM-Plan)

Implementing BIM effectively requires profound changes in the way DCO players work at almost every level – not least with regards to communicating information exchange requirements. Players have found difficulties with aligning information expectations and opportunities to delivery extra value to projects and leverage the benefits of BIM have been limited.

On collecting qualitative data associated with BIM planning and information exchange, it was clear that a number of organisations had already thought about BIM planning and some have even created templates that enable a level of strategic decision making on a project. Approaches and content however are discrete and tend not to move beyond detailing aspirational BIM goals.

The result of deploying the BIM PEPG, even in a limited fashion, has revealed its potential to address matters of consequence relating to information exchange. This is not to say that the BIM PEPG is the only solution, but it points us in a direction that enables DCO players to focus on utilising their BIM resources in an intelligent way.

A BIM-Plan should include tools to enable teams to make collective strategic decisions on: which BIM-Uses to deploy, whether there is the competency in the team to implement each use, sequential timing of BIM Uses, value to the project, what to deliver, and assigning responsibilities. With these in place, teams can focus on the task in hand – populating the model(s) with the correct data and thereby ensure that downstream information needs are met without the need for re-work.

A potential exists to have a national standard Strategic BIM Implementation Plan which can be deployed on a project basis and from those DCO participants interviewed as part of this research, a consensus materialised suggesting that it would be of benefit to the nation to do so.

4.4 The Need for Professional Guidelines on Leveraging BIM and Sharing Meaningful Information

DCO players are starting to leverage BIM benefits through the deployment of smarter tools, however the promises of the full capability of an integrated BIM team that will enable facility lifecycle management remain more remote.

In the absence of a mandate demanding the use of BIM, it may seem immaterial to have national guidelines. But change doesn't happen overnight (particularly in the construction sector), and if Sweden is to maintain competitiveness on the international stage as well as enable better collaborative working, a national BIM vision through guidelines is necessary to guide the nation towards consistency and an integrated approach.

The development of key concepts like *delivery specification* (considered in Paper #2) into a form that DCO players can use to support information exchange can be seen as an essential component together with collaboration supporting mechanisms and utilisation of strategic BIM execution and planning tools.

Model authors need to be aware of simple matters like what to model and what not to. Once organisations build up experience on such matters, DCO players will be in a position to respond when BIM is mandated and proceed with confidence and consistency.

4.5 The Need to renew contractual forms to actively support BIM collaboration and integrated processes

It has been suggested¹⁰⁵ that in order to advance toward integrated BIM (BIM maturity Level 3) new procurement models which consider ways of harnessing the skills of all of the parties involved in the design, construction and management of a building will need to be developed alongside the new collaborative and multi-party contractual documents.¹⁰⁶ Furthermore, one of the greatest industry challenges relates to the implementation of working standards and training - particularly in relation to teamwork and collaborative approaches. Contractual forms must support BIM workflows in an active way that enables teams to work better together with the product and project outcome in focus.

Paper #3 considers the deficiencies of existing appointment documents and procurement methods in Sweden in relation to BIM collaboration and what measures may be taken to mitigate barriers to the collaborative processes at the core of BIM implementation.

Whilst Sweden benefits from a positive culture of collaboration and openness which hitherto has been exploited effectively in connection with the use of BIM and data sharing, a number of key questions including the status of model content and how the information may be used by other parties remain both theoretic and practical problems.

On considering propositions on how we can reduce, remove or change collaboration barriers, a first step may be to standardise those mechanisms that are key to collaboration and meaningful information authoring and sharing. The supporting mechanisms described may be seen as key to a move towards a more integrated approach.

¹⁰⁵ BIS (2011) *BIM Management for value, cost and carbon improvement: A report for the Government Construction Client Group – Building Information Modelling (BIM) Working Party Strategy Paper*, London.

¹⁰⁶ RIBA (2012), *BIM Overlay to the RIBA Outline Plan of Work*, RIBA Publications, London.

On summing-up:



"Be yourself and think for yourself; and while your conclusions may not be infallible, they will be nearer right than the conclusions forced upon you."
(Elbert Hubbard)¹⁰⁷

5.0 Discussions & Conclusions

This chapter discusses the findings and scrutinises what they might mean. The findings are discussed and analysed with reference to the theory, ideas, issues and problems that have been noted earlier. Here the 3 research questions are revisited and examined. The consequences of the research results and their application are then considered together with a note on validation and their ability to be generalised. The chapter concludes with reflections, contribution to the field and suggestions for further research.

5.1 Research Questions revisited

The 3 research questions that this research project aimed to answer are repeated below. The questions are answered in order under respective headings with support from the results and discussions in the previous chapter.

¹⁰⁷ Elbert Hubbard - American editor, publisher and writer (1856-1915)

5.1.1 Research question #1 (on Standards & Information Exchange)

What in the way of development / standards / guidelines are needed to support the implementation of BIM in connection with construction projects in Sweden with a specific focus on information exchange and delivery specifications?

The findings from Paper #1 together with the outcome of the review of guidelines presented above come to bear on research question #1 in so much that they identify what is missing in the way of guidelines and what could be done to address deficiencies in terms of content, scope and positioning.

It is established that to support meaningful information exchange and the downstream usability of design team authored data, some form of strategic planning is required. The BIM PEPG is tested to determine its suitability to complement the existing administrative guidelines (BH90) and the results suggest that the deployment of a strategic execution plan, like the BIM PEPG, offers teams the strategic insight needed to implement BIM intelligently, support information exchanges and enable teams to leverage the technology more effectively.

A significant difficulty exists however in fully implementing a strategic execution plan from the outset. Typically not all of the project team can participate – due amongst other things to timing of appointments and scope of work – meaning optimum value cannot be brought to project at the critical early stages. This issue is taken up through research question #3 and in the context of contractual hindrances to BIM collaboration.

The results from the pilot study and associated case indicate that authored design data can be created, utilised, shared and bring added value to the project, in a way that is often neglected in traditional practice. Proper BIM planning appears to have good practical application that may offer organisations opportunity to improve project outcomes through contribution to collaborative processes deemed to be at the core of BIM use.

Where a strategic BIM Plan is carried out, teams have the possibility to deploy resources smartly and with overall project goals agreed, members can focus on the creation, utilisation and sharing of data necessary to achieve those objectives.

5.1.2 Research question #2 (on Delivery Specification)

How could BIM-Info delivery content be articulated in a commonly understood manner on a project basis? Could a standard matrix be established that could be used for various BIM-Uses at various project stages that would help align information delivery expectations?

Key findings revealed in paper #2 provide an insight into responding to research question #2 through a proposal for a standard method of producing an information delivery specification for supporting information exchanges associated with specific BIM-Uses.

The process involves 3 key stages being:

- ✦ Establish *BIM-Uses*
- ✦ Establish *BIM-Info* Content.
- ✦ Create *BIM-Delivery* Schedule.

Specification itself requires 8 key parameters to articulate information content being:

- ✦ Information Exchange No.
- ✦ BIM-Use
- ✦ Delivery Date
- ✦ BIM-Info Classification
- ✦ Responsible Party
- ✦ Level of Detail
- ✦ Receiving Party
- ✦ Delivery Format

The resultant protocol attempts to address the need for DCO players to better align information requirements and helps structure information production (model authoring) into a logical sequence that negates re-work and lost opportunities to leverage the data. If standardised and brought to mainstream use together with the other measures mentioned, it could contribute to practice communications and avoid the risks associated with divergent approaches.

The employment of emerging concepts like *level of detail*, *model author* and the utilisation of suitable building parts classification are central to communicating digital content and the underlying theory of buildingSMART's standardisation efforts have offered instruments to develop simple, user-friendly communication-support mechanisms.

Ideally one would want the delivery specification to be automatically generated from one's BIM authoring tool (eg Revit or ArchiCAD) in the same way a window schedule is. This of course eliminates the mundane task of manually creating and maintaining a schedule, removes the possibility of human error and ensures proper coordination.

Authors can then easily check that their model contains the correct objects and properties to enable, for example a particular simulation to be carried out, without proceeding in error.

In this sense the delivery specification can function as an early warning system to aid and guide design authors to generating the right information for the right purpose – whether it is for a specific information exchange or to carry out specific BIM-Use, for example, cost control at scheme design stage.

It is clear that with so many possible uses, users and application for digital construction information through the DCO process, the individual user of the information (or organisation) may be best placed to make demands for information requirements.

It is here that the delivery specification has particular strategic application. Downstream users of the digital construction information, for example Facility Managers, can use a standardised delivery specification to communicate to design authors their information requirements. This way key information can be authored early (if deemed to add value) and re-work, duplication of effort, and waste can be avoided.

A first step in this process is for DCO players to understand what parameters are important and secondly to become aware of what objects and properties should be authored, when, ie; establish a logical information order with cognisance to a strategic BIM Plan. This is a learning process, and only through lengthy application can patterns be recognised that may lead to further standardisation.

The Information Delivery Protocol (IDP) can be seen as a viable contribution to the development of smart authoring, and standardisation of process. It takes forward the general key ideas behind Information Delivery Manuals (IDM) and Model View Definitions (MVD) and may offer practitioners scope to start operating with such exchange methodologies.

5.1.3 Research question #3 (on BIM Collaboration)

How can we reduce or eliminate contractual hindrances to BIM collaboration?

The results from the investigations carried out in connection with Paper #1 and Paper #2 raised the following fundamental question:

If it seems a 'good idea' to have a project specific BIM implementation plan and use delivery specifications to ensure greater certainty, align information expectations and enable greater downstream cognisance of information needs, then why is this not happening?

Discussions with industry collaborators suggest that the timing, scope of supporting mechanisms with contractual relations present significant barriers to, amongst other things, the facilitating processes outlined in Paper #1 and Paper #2.

This leads to the hypothesis that:

Existing contractual forms, including ABK 09, AB 04, ABT 06 do little, if anything to support the necessary collaboration at the core of BIM processes, contain little, if any BIM decision support mechanisms and, as they stand, present something of a hindrance to enthusiastic organisations endeavouring to break through to BIM implementation level 3.

Paper #3: *Contractual Hindrances to BIM Collaboration* aims therefore to tackle this purported phenomenon with cognisance to developments in this area elsewhere and, through focus group interviews together with document review, propose hindrance mitigating methods that might to applicable to the Swedish DCO sector.

In response to the question of how we can reduce or eliminate contractual hindrances to BIM collaboration, Paper #3 suggests a series of standard decision support mechanisms that could be deployed together with the *Totalentreprenad* (Design & Build) procurement form that may enable participation and input from an extended project team.

A standard BIM-Addendum may resolve some of the confusion around existing appended documents and facilitate the strategic processes discussed in Paper #1 and Paper #2. Results suggest that 5 key elements should be included in a BIM-Addendum which collectively can be seen to actively support early collaboration on BIM projects. These include:

- ✦ Project-based BIM-Plan
- ✦ Object Author Matrix
- ✦ Level of Detail Schedule at each Stage
- ✦ BIM-Delivery Schedule
- ✦ BIM Authorised Uses Schedule.

5.2 Consequences and Possibilities

Examining DCO business processes to determine how we can improve communication and coordination of digital information is not so different than a team coach developing and implementing new plays. The goal is not to complicate our work with endless introspection and analysis. Instead, the aim is to examine and implement options that allow us to achieve peak performance and effectively move the ball toward the goal: designing, building and operating a facility more efficiently and truly meeting the needs of our clients.

The aforementioned measures may go some way to providing DCO players with the necessary support to kick the ball into touch.

5.2.1 General observations

An observation over this study that was particularly telling is the propensity for organisations to muddle through on the back of their own initiatives and good will amongst team members. There have been many attempts to bring about BIM implementation standards through various CAD or IT Manuals, with little effort to identify what is central and what is peripheral.

There is the tendency to start well but when nobody is looking, revert to old practices. This is why more than internal initiative may be needed to steer a sector toward a consistent BIM approach – an element of compulsion centred round a national consensus of best practice may not be a bad thing.

This thesis often refers to conditions relating to the *Swedish* DCO sector or context. It does this because the conditions and circumstances under study relate to phenomenon experienced in Sweden. That is not to say similar conditions do not exist elsewhere, but it is fair to say that the circumstances Sweden finds itself in are rather different from its Nordic neighbours – particularly when it come to drivers and standards.

In this capacity it is possible that different nations may be seen to have a different set of issues to address. Notwithstanding this, it is also entirely possible that many of the findings can be generalised and may be deemed applicable elsewhere. Take for example the matters discussed relating to contractual hindrances to BIM collaboration – this is known to be as much an issue in the UK as it in Sweden.

5.2.2 Application in the industry

The results of this research effort remain conceptual, however application of the processes described are sufficiently mature to provide, particularly design participants, strategic insight into improvement areas.

The proposed prerequisites – *Standards, Delivery Specification, and Collaboration Support* – can improve the management of digital information and strive to enable a more integrated approach through enhanced cross-discipline collaboration. However, they need to be applied correctly and in a way which does not conflict with other requirements. As with any new methodology or process, willingness, education and time are essential. In this respect it is suggested that an incremental application of the processes be deployed with full team buy-in as an initial goal.

A next step may be to generate draft standards that can be trialled over a certain period to enable the industry to reach an open consensus. The research findings indicate that

consistency is critical, and in any case, some form of national vision, based on open standards appears to be the logical approach emerging elsewhere.

5.2.3 Practical benefits and barriers

Architects and technical consultants have been quick on the uptake of BIM technology since it has been readily recognised to support their existing activities better than 2D CAD. The possibility to carry out automated 3D collision control, amongst other things, has accelerated consultants use. However model-based design requires standards otherwise the communication and coordination problems witnessed set in.

BIM technology in itself cannot contribute to solving the individual, organisations, or sectors problems; in fact it can be said to create a whole new set of problems. The processes described seek to offer some practical benefits by helping organisations overcome implementation difficulties and thereby enable BIM benefits to be realised.

One of the barriers to practical uptake of the suggested processes is the time it takes to create and maintain a culture of collaboration; enabling a suitably functioning socio-technical system to exist. Individuals and organisations are impatient and want to experience personal benefits quickly, when perhaps the focus should be on the success of the project.

It has been suggested¹⁰⁸ that in Sweden the drive for BIM implementation is being lead by a small number of technical enthusiasts, not by client demand (as is to be found elsewhere). With this in mind it is difficult to imagine convergence of approach and the production of common implementation standards emerging without some form of standards body taking the initiative. Furthermore, a fragmented sector, with individual organisations looking after their own interests, serves as no vehicle for an easy transition towards a more integrated approach, quite the opposite. For this reason, the push and pull of BIM implementation in Sweden may need to change its dynamic.

With reference to successes in other countries, where BIM is mandated, standards are in place, and clients are driving BIM implementation, organisations are forced to think outside their own boundaries and place the project in the centre. But the state is less convinced of the necessity to mandate BIM, and perhaps for good reason has largely stayed out of the BIM debate. There is a strong argument that the construction industry should be left to its own devices and market demand will dictate the need for and success of innovative interventions. However, this stand point may leave the Swedish DCO split, lacking in expertise, and struggling to catch up with its Nordic neighbours with regards implementation maturity level.

¹⁰⁸ OpenBIM (2010), *OpenBIM Introductory Presentation* (Powerpoint Presentation), OpenBIM, Stockholm

BIM and associated integrated activities offers an opportunity to mend something of the fragmented nature of the construction industry.

5.3 Validation of Results and Generalisation

Since this research is largely based on *qualitative data* from *case studies* it can be notoriously difficult to generalise from results. Here it is perhaps suitable to acknowledge the inherent limitations of the methodology, namely the fragility of results based on case materials and qualitative data.

What can be said of the results is that they present insight towards possible solutions to familiar problems the DCO sector faces today.

The results are based on a limited set of data from case and interview sources – mostly for practical reasons – and as a result, the validation of the research ideas presented is limited in capacity. However, the data collected can be considered representative, the cases themselves typical and therefore a degree of reliability can be concluded on the basis of the research undertaken.

Resource constraints meant however that only a limited number of cases could be reviewed and interviews conducted, and perhaps some reservations about the authenticity or accuracy of responses may be applicable.

It is always risky to attempt to generalise from results based on selected cases and for this reason it is wise to exercise caution. To say the cases were typical only provides a certain mileage when it comes to generalisation. One size does not necessarily fit all but the suggested processes and decision support mechanisms are intended to incorporate sufficient flexibility to have universal application.

Whilst it is recommendable that the described processes and decision support mechanisms become branch standard, they are a long way off being so. However, publication in a form that is usable, followed by lengthy trials may enable sufficient validation for some form of *de facto* standard to emerge that is reminiscent of this research work. Which concepts will die, which will survive is down to the process of evolution.

5.4 Reflections on Methods, Theories & Findings

With the work done, it is often of value to take a retrospective view and include some reflections on the research undertaken. In this respect it can be useful to consider responses to the following questions:

Method

- ✦ With hindsight, were the right methods used? – Here one can say that the case method is particularly suited to research related to improving processes within the construction industry which is of course itself a project-based industry. For proposals to gain credibility, test cases with tangible results are essential. Notwithstanding this, it may have produced more certain results had mixed methods including survey been adopted.
- ✦ Was enough of the right kind of data collected? – Whilst more data through more tests may have build greater robustness, the qualitative data collected did serve to adequately support the underlying theories.
- ✦ Did the data collected produce data that is representative, valid and reliable? – In so far as is reasonably practicable. A number of different sources where tapped which helped corroborate the data.

Theories

- ✦ Which of the theories or hypothesis were proven, considered plausible or disproved? – All hypotheses were considered plausible and may provide a solid basis for further research. Guidelines, for example, have had a significant bearing on the research and results may enable teams to focus on *here and now* solutions. BIM as socio-technical system is a fundamental theory that the study supports. Here results may be viewed as a contribution towards the *Information management and coordinated working practices* (see Figure 17) bridging technical and social aspects of the system.
- ✦ Were any theories flawed? – Theories were updated and revised as the project moved forward. Some theories that were initially considered relevant or pertinent were later rejected or modified to accord with results – for example, in the early days of the research, it was conjectured that consults could simply adopt a *BIM Execution Plan* and that this by itself may offer something of a breakthrough in communication difficulties. However, it was later revealed that contractual relations; timing and scope of appointment present a hinder to execution.
- ✦ Do the results support the theory or aid formulation of a new theory? – The results generally support the theories presented. What is interesting to reflect on is the links between the various theories and the way in which this study shows how action in different areas may interact. *Guidelines – forms of agreement – BIM as socio-technical system – pull and push of BIM implementation* together have generated an interesting dynamic that may warrant deeper investigation.

Results

- ✦ Are the results conclusive? – The results here represent an interim report of a larger study and attempt to identify and test ideas that may enable teams to move towards a more integrated approach regarding information management. Consensus behind implementation prerequisites may only be achievable through extensive trialling which has, so far, been outside the scope of this study.
- ✦ Is there something you would have done differently? – It may have been fruitful to tap into the initiatives of openBIM more and gain industry comments and feedback through their forums.
- ✦ What are the limitations of the results? – A lack of validation somewhat limits the results; however this matter together with depth of investigation can be addressed in the 2nd phase.
- ✦ What is the significance of the results? – The results represent a set of possible preconditions to successful BIM implementation. The potential advantage of adopting standard communication protocols has enormous industry significance since the production and communication of design information presents organisational difficulties which can be better managed.
- ✦ What new knowledge has been gained? – New knowledge has been gained in the following areas: guidelines gap, the need for BIM planning, the need to focus on implementation of strategic BIM-Uses based on team competencies, the key components and application of digital delivery specification and insight into possible BIM collaboration decision support mechanisms.

5.5 Contribution to the field

This research contribution relates to previous research into the adoption, implementation and development of BIM standards. It seeks to build on this existing knowledge by proposing and testing measures that may enable better information management, exchange and collaboration that is needed to lift BIM implementation to the next level.

The key outcomes are contributions in the following areas:

- ✦ Understanding the barriers to BIM use in practice and helping practitioners to overcome these.
- ✦ Insight into the effect of deploying a strategic BIM execution plan to support information exchange and coordination.
- ✦ Contribution towards the ongoing development of buildingSMART's IDMs for practitioner and client use.

- ✦ Definition of a method of articulating BIM information content requirements for key BIM uses, namely, design coordination and energy simulation.
- ✦ A development of a digital delivery specification.
- ✦ Identification of deficiencies in existing standard guidelines and recommendations for improvement.
- ✦ Contribution to the development of a university based BIM lab - for both testing and validating BIM methodologies, standards and protocols as well as for student and practitioner training.

5.5.1 Scientific contribution

The output from this research project which amounts to a series of recommendable BIM processes that the study considers as prerequisites to BIM implementation, has been undertaken through employment of recognisably scientific methods and seeks to contribute to science as a model for BIM implementations – towards a more integrated approach.

The research effort provides a useful contribution to knowledge through making a difference to standard practice methodology and providing industry & academic insight to improved efficiency, certainty, and accountability to the DCO industry. The results speak for themselves and represent a practical, functional and constructive contribution to the state of art within this research field.

5.5.2 Practical contribution

The prerequisites suggested are also a practical contribution as, while based on theory, are targeted for use in practice and are off practical application. There often simply isn't time to test and evaluate improvement possibilities in the rush of daily practice. This work therefore aims to open up new possibilities that practitioners have not the time to explore.

Through the necessary interactions with consultant practitioners, and the collection of pilot, case and interview material, an increasing interest amongst industry representatives has emerged. Methods to improve communication and coordination are often on the top of most agendas and with BIM being such a hot topic, industry awareness has been inspiring and motivating.

Furthermore, this work is targeted at offering a contribution towards the (future) generation of applicable national standards for BIM implementation. In this capacity, it is suggested that strategic BIM guidelines must complement the existing administrative guidelines and that a standard BIM collaboration addendum be prepared that can be appended to BIM project contracts.

5.5.3 Coordination at Sector Level

One must also consider how these efforts could be supplemented by coordinating efforts at sector level to avoid problems of sub-optimization and conceptual divergence. In this respect this work has been carried out in coordination and collaboration with key current sector initiatives lead by SBUF and openBIM. Specifically, it relates and dovetails with 2 current SBUF research projects coordinated by openBIM, namely:

- ✦ BIM och Avtalsformer - En jämförelse mellan befintliga avtalsformer och Integrated Project Delivery,¹⁰⁹ which represents a development of Paper #3: Contractual Hindrances to BIM Collaboration.

And

- ✦ Detaljeringsnivå i BIM,¹¹⁰ in which the author participated as reference group member.

One of openBIM's tasks is to coordinate sector standardisation efforts around the use of BIM in Sweden.

5.5.4 Contribution to learning

An important part of this research appointment has been to establish a university based lab for both testing and validating BIM methodologies, standards and protocols as well as for student training.

The lab, now established at Lunds Universitet, Lunds Tekniska Högskola (LTH), Campus Helsingborg, is intended to mirror Denmark's Technical University's (DTU) BIM Lab established in 2007. LTH's new facilities, resources and courses now come to serve south Sweden's architectural and engineering students, and wider AEC community. By establishing such resources both sides of the Öresund, and with broad consensus in working methodology applied at both institutions, a significant contribution towards the aspirations of the Interreg IV project is anticipated through harmonisation of BIM working practices and knowledge / expertise transfer through open courses.

¹⁰⁹ Qvarnström, G., Ask, A., Hooper, M. (2012) *BIM och Avtalsformer - En jämförelse mellan befintliga avtalsformer och Integrated Project Delivery, IPD*, SBUF-projekt med OpenBIM, Sweden.

¹¹⁰ Gustavsson, H. et al. (2012) *Detaljeringsnivå i BIM*, SBUF-projekt med Skanska, Sweden.



Figure 42: SimsalaBIM: LTH's Building Information Modelling Development Laboratorium

In addition, the teaching carried out at the lab has both provided new industry professionals a strategic insight into using BIM tools and understanding BIM process and furthermore has inspired a number of noteworthy Masters Dissertations, supervised by the author, including:

- ✦ *BIM-kapacitet och mognad - ett test av bedömningsmetoder på entreprenad- och konsultföretag.*¹¹¹ (BIM Capability and Maturity – An assessment procedure for consultant and contracting organisations.)
- ✦ *Framtagning av BIM-objekt för byggsystemleverantörer.*¹¹² (Production of BIM objects for building system suppliers.)
- ✦ *Hur kan processerna i en installationsentreprenad effektiviseras?*¹¹³ (How can MEP contractors streamline processes?)

5.6 Suggestions for Further Research

This section considers proposals for the development of this research, an extension and deepening which could be of interest from both a research and an industry perspective.

This work – being a licentiate thesis – represents a midway testimony to an ongoing research project dedicated to advancing the state-of-the-art with BIM implementation. So far some reasonable conclusions have been drawn from the results that the collected data has offered. However a weakness is that the current research lacks a level of validation, further case applications could serve to strengthen the research and enable a more in-depth study of implementation prerequisites.

¹¹¹ Agha, R. & Dübeck, M. (2011) *BIM-kapacitet och mognad - ett test av bedömningsmetoder på entreprenad- och konsultföretag*, Examensarbete, Lunds Universitet, Sweden.

¹¹² Lindros, M. & Hansson, P. (2012) *Framtagning av BIM-objekt för byggsystemleverantörer*, Examensarbete, Lunds Universitet, Sweden.

¹¹³ Hansson Drews, E. & Länn Lundin, J. (2012) *Hur kan processerna i en installationsentreprenad effektiviseras?*, Examensarbete, Lunds Universitet, Sweden.

In proposing suggestions for the further development of this research many avenues present both worthy and interesting possibilities. One area may be to develop the tools and technology to automate those processes of BIM planning, information exchange and coordination, even collaboration planning. Standardising and automating those routine activities is an area where large potential improvements can be made and significant efficiency gains realised.

But one can also address the methodological, process and organisational aspects which so far, this study may only have made limited impact. The implementation supporting mechanisms studied allow teams to plan ahead and articulate intentions regarding the flow and use of digital information, but do not address the logistics of integration into standard practice procedures and how they may work on a larger scale. The delivery specification could be tested in conjunction with a broader range of information or BIM-Uses – perhaps using the IFC data model. For this reason it can be seen as recommendable to extend this research by hammering out further preconditions for success – this might include considering the compatibility of the aforementioned implementation processes within an existing socio-technical system.

Section 4.3 – 4.5 outlines a plausible basis for an extension of this research, being a deeper analysis of:

- ✦ The Need for an Effective Implementation Strategy (A BIM-Plan).
- ✦ The Need for Professional Guidelines on Leveraging BIM and Sharing Meaningful Information.
- ✦ The Need to renew contractual forms to actively support BIM collaboration and integrated processes.

In conclusion it is generally felt that in order to achieve the optimum impact of this work the next stage should endeavour to delve deeper and go into more detail on these specific parts. This could be done, for example, through a case analysis of a mega-project or even individual studies. Any future work however, must be considered in the context of international developments and coordinated at sector level in order to have the full desired effect.

5.7 To Close

Successful implementation, hidden in the forest like a shy deer, is to be reached not by avoiding disappointment and set-back, but by recognising its role as a natural, inevitable step on the way to reaching anything good.

Why? Because no organisation or set of organisations are able to produce a great work without experience, nor achieve a worldly position immediately, nor fall on superior results

at the first attempt. In the interval between initial failure and subsequent success, in the gap between how we wish one day to perform and how we perform at present, must come pain, anxiety, envy and even humiliation.

However, we must not be tempted to withdraw from challenges that might have been overcome if only we had been prepared for the perseverance demanded by almost everything valuable.

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- ✦ Eurostep: <http://www.eurostep.com/>
- ✦ Google Scholar Search Engine: <http://scholar.google.com/>
- ✦ Journal of Information Technology in Construction: <http://www.itcon.org>
- ✦ Statistics Sweden: <http://www.scb.se/>
- ✦ Swedish Standards Institute: <http://www.sis.se/>
- ✦ Svensk Byggtjänst: <http://www.byggtjanst.se/>
- ✦ Whole Building Design Guide: www.wbdg.org
- ✦ DemoHuset: www.demohuset.se
- ✦ Statsbygg: www.statsbygg.no
- ✦ McGraw-Hill Construction BIM: www.bim.construction.com

- ✦ Building Information Modeling Trends SmartMarket Reports:
www.analyticsstore.construction.com
- ✦ buildingSMART Alliance: www.buildingsmartalliance.org
- ✦ HOK: www.hok.com
- ✦ Mortenson Construction: www.mortenson.com

Appendix

Appended Papers

The following scientific articles are appended to this thesis:

Paper #1:

- ✦ Hooper, M., Ekholm, A., (2010) A Pilot Project - Toward BIM Integration - An Analysis of Design Information Exchange & Coordination, *Proceedings of the 27th Annual CIB W78 International Conference - Applications of IT in the AEC Industry*, Cairo, Egypt. 15-17 November 2010.

Paper #2:

- ✦ Hooper, M., Ekholm, A., (2012) A BIM Delivery Protocol, *Australasian Journal of Construction Economics and Building, Special Issue on BIM*, Sydney, Australia.

Paper #3:

- ✦ Hooper, M., Ekholm, A., (2011) *Contractual Hindrances to BIM Collaboration*, LTH, Lund, Sweden

It is intended that this paper will be submitted to the peer-reviewed journal: Construction Economics & Management.

Appended Documents

The following supporting documents are appended to this thesis:

Document #1:

- ✦ BIM Implementation – Guidelines for Architects and Engineers

Document #2:

- ✦ A Review of BIM-Guidelines: Content, Scope & Positioning

Conference Articles and Reports

- ✦ Hooper, M., Ekholm, A., (2011) A Definition of Model Information Content for Strategic BIM Implementation, *Proceedings of the CIB W078-W102: 2011 Joint International Conference*, Sophia Antipolis, France, 26-28 October 2011.
- ✦ Qvarnström, G., Ask, A., Hooper, M. (2012) *BIM och Avtalsformer - En jämförelse mellan befintliga avtalsformer och Integrated Project Delivery, IPD, SBUF-projekt med OpenBIM*, Sweden.
- ✦ Gustavsson, H. et al. (2012) *Detaljeringsnivå i BIM*, SBUF-projekt med Skanska, Sweden.

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Paper #1:

**A Pilot Project - Toward BIM
Integration - An Analysis of
Design Information Exchange
& Coordination**

Published in 2010: Proceedings of
the 27th Annual CIB W78
International Conference -
Applications of IT in the AEC Industry,
Cairo, Egypt.

Authors: Hooper, M. and Ekholm, A.

A PILOT STUDY: TOWARDS BIM INTEGRATION - AN ANALYSIS OF DESIGN INFORMATION EXCHANGE & COORDINATION

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ABSTRACT

Construction projects are costing too much and taking too long as a consequence of unnecessary omissions and errors in project documentation and sub-optimal coordination of design information between consultant disciplines. The theory behind BIM provides an exciting integrated solution for project information management, however in this new process further effort is required to define the content of information deliveries and a number of basic who?- what?- when?- how?- questions relating to object and property definitions need to be resolved.

This study investigates and attempts to define the functional requirements for integrated information management through the design stages of a construction project focusing on architectural practice requirements within the residential sector in Sweden. In a pilot study concerning a residential construction project in Sweden the buildingSMART Alliance's new *Building Information Modelling Project Execution Planning Guide* was applied. The principle BIM planning procedures are applied to the case, tuning requirements to the specific project and localised to support Swedish classification standards. Through the enquiries required to develop and define these processes, a new information exchange protocol emerges, tuned to the Swedish residential sector.

Keywords: BIM, information exchange, design coordination.

1 INTRODUCTION

1.1 Background

In recent years there has been an international explosion of interest in the development of BIM in the construction sector. Actors are gradually developing the skills and personnel to implement BIM and are starting to leverage some of the benefits of working with intelligent 3D objects in a virtual building design environment (Eastman et al 2008).

One reason for an increase in this adoption is that traditionally much project information and development relies substantially on human input and subsequent multiple manual checks and cross-referencing operations which, on complicated projects, inevitably leads to errors or missing information leading to extra cost and waste (Cohen 2010).

Construction projects are becoming increasingly complicated in nature, requiring more specialist discipline input resulting in a much greater volume of technical information which in turn requires to be coordinated and kept up-to-date and relevant through the life cycle of a project. In such contexts conventional project filing systems and information work-flows are becoming un-manageable and there appears to be a need for user friendly practice guidelines to supplement existing standards which if adequately tested, could form a key part of an Information Delivery Manual (IDM) or even a National BIM Standard.

In Scandinavia, where building is generally more expensive than in central and southern regions of Europe (Statistics Sweden, 2009), there is a concern expressed throughout the industry that building productivity must be increased. In conjunction with the new processes implied by BIM for design delivery,

construction and facilities management, an industry-informed information exchange protocol should be able to contribute toward providing better value.

BIM, amongst other things, seeks to streamline processes, present construction information in an accessible and common way, minimise the possibility of missing or clashing information and ensure optimised project coordination. The real value of BIM to any organisation be it a design firm, construction firm or building owner, is in leveraging the structured information contained in a building information model to create value (Jernigan 2008).

To implement BIM and tap into leveraging efficiency benefits an organisation must first consider a critical evaluation of its core competencies and business objectives, followed by strategic deployment of appropriate technology to take the guesswork out of business decisions and shift the organisation's output from traditional routine, low-value-added tasks and services toward high-value-added tasks and services (Smith 2009).

For design firms, this means investing in tools and implementing business processes that are essential to increasing efficiency, productivity, profit, and value. There is a need for a new focus on providing sustained value to clients, eliminating or reducing inefficiencies in the process and eliminating repetitive and mundane tasks.

1.2 Problem statement and research questions

The theory behind BIM provides an exciting integrated solution for project information management, however, in this new process a number of key questions need to be resolved: Who is involved? What models are required and why? When are the models needed? What should the models contain? How are the models exchanged? Who manages the process?

Whilst some of these matters may be obvious in a traditional method or design methodology, new processes with new responsibilities are emerging which need to be defined in order to facilitate optimised design co-ordination and integrate BIM into working practices. The research question investigated in this study is how the new process requirements may be handled in a systematic way.

1.3 Purpose and objectives

This study aims to assist in and promote the adoption of BIM technologies in the Swedish architectural, engineering, construction & facilities management (AEC&FM) industry, and try to avoid the uncertainty and disparate approaches that created inefficiencies with the implementation of 2D CAD over the past three decades (Jernigan 2008).

Many business aspects are affected through full and effective BIM implementation. By viewing the implementation process and the act of exchanging information as a role of information stewardship (Smith 2009), the study aims to test and reveal the results of mechanisms facilitating and constraining BIM integration through an analysis of identified BIM uses, designed implementation processes and developed information exchanges.

This objective is pursued by: 1) a study of a residential construction project with a major architectural practice in Sweden; 2) a series of workshops with design consultant participants involved in the development and use of BIM in connection with the studied project; 3) an analysis of empirical data collected by the application of the buildingSMART Alliance's new Building Information Modelling Project Execution Planning Guide (hereafter referred to as the BIM guide) (Anumba et al 2009).

One of the first steps in any research process is to assess the potential for improvement in order to tune the study focus towards a defined purpose in which a valuable contribution towards development in the field can be realized. The purpose of this initial pilot project is amongst others: to measure and evaluate how far BIM has come in practice; to identify issues of information exchange; to record current practice methodologies; to explore possibilities for improved efficiency and error mitigation; to create an example of set-up guidelines for residential projects; and to develop a proposal for an information delivery matrix.

1.4 Focus and delimitations

This project focuses on information delivery through the design phase of residential projects with the aim of moving towards an optimised system of design material delivery for this type of project. It is intended that further studies will facilitate analysis beyond design stage and out-with the residential sector, however this provides a sound starting point.

The instances of information exchange here centre attention on those commonly understood to be those carried out through the design phase.

2.0 METHODOLOGY

As a starting point an extensive literature review was carried out with particular attention drawn to the various BIM Manual / BIM Guideline documents now emerging around the world through organisations such as the buildingSMART Alliance. Information is not lacking, however, practical experience in moving forward with BIM beyond office boundaries in Sweden still is in its infancy.

Following an investigation of existing literature and other published guidelines, the BIM Guide provided a suitable supporting platform to launch a study focused on shaping an overview of the use and benefits of BIM on a typical residential construction project and exercising a method of reaching a common agreement with regards to information exchange and extent of implementation.

2.1 Case study design

The case study is preferred in examining contemporary events and when relevant behaviours cannot be manipulated. Two important sources of evidence are: direct observation and systematic interviewing. The case study's strength is its ability to deal with a full variety of evidence - documents, interviews, and observation - beyond what might be available through other research approaches (Yin 2003).

Through its natural setting, the case study provides an ideal practical real-life context and a suitable grounded platform to consider and test strategic decisions with regard to information exchanges thereby creating an opportunity to introduce a move towards BIM implementation in practice.

A pilot project has been launched, establishing a collaboration between academic experts at Lund University and industry through White Architects. The purpose is to initiate a strategic study centring on the question of BIM implementation in construction, and specifically information exchange, with an aim to solve some of the structural and organisational issues associated with this new working method in Sweden.

Common goals are to establish a documentable and transferable method of overcoming difficulties in implementing BIM focusing on practical solutions to advance information exchange.

The known attributes of this case project fit well with the opportunities to break new ground in BIM implementation. The project's simplicity, reality, and that it is at an early stage of development present an opportunity to make a fresh start and facilitate optimal leverage of results. Its relevance to the generic problems outlined in the problem statement and transformed into research questions are direct and represent real practical issues to be solved. The study provides a basis for a deeper understanding of specific practice-related issues in their natural setting.

Since new build housing represents a significant market within the construction industry - not least in Sweden - this case study project may be deemed typical as an instance to study. The case being typical, it is likely that the findings can be generalised and therefore applied elsewhere.

2.2 Data collection and case description

The collection of empirical material has been assembled to firstly facilitate a deeper understanding of the context in which BIM is being adopted and used and secondly articulate the current status of BIM implementation in the organisation under study.

To meet these objectives a series of workshops were carried out in connecting with the Gyllins Trädgård project together with the project architect and BIM experts within White Architects organisation. The project is live and provides a real-world setting for the study, facilitating a grounded source of valid data collection.

Through the enquiries required to develop and define the BIM implementation processes described in the BIM guide, valuable data has been collected, organised and analysed. The guide's planning procedures forms the basis of the dialog with White and has enabled a pedagogical and thorough approach whereby data has been collected for the purposes of analysis and system optimisation for future projects.

3.0 THEORY

A number of national standards and BIM guideline documents exist around the world. Amongst other things, it is the task of the buildingSMART alliance to harmonise documentation and BIM implementation

methods on a national and international level. The US NBIMS was one of the first comprehensive national standards (NBIMS 2007), with Norway, the Netherlands, Denmark and Australia also producing various forms of national guidelines (eg Denmark's 3D Arbejdsmetode).

In Sweden the principle guidelines are to be found within *Bygghandlingar 90 : byggsektorns rekommendationer för redovisning av byggprojekt. Del. 8: Digitala leveranser för bygg och förvaltning* (SI 2008). This document contains guidance on the administrative aspects of BIM with reference to other Swedish standards, however lacks a strategic standard method of planning and agreeing amongst project team members a process of BIM implementation with a focus on information exchange. Here the buildingSMART alliance's BIM Guide may be able to bridge the gap.

The BIM guide is a product of the BIM Project Execution Planning buildingSMART alliance™ Project and was developed to provide a practical methodology for project teams to design their BIM strategy and develop a BIM Project Execution Plan. The main concepts behind the guide have been developed to complement the long term goals of the buildingSMART alliance in the development of a standard that can be implemented throughout the AEC&FM industry to improve efficiency and the effectiveness of BIM implementation on projects.

4.0 IMPLEMENTATION

4.1 Case Study: Gyllins Trädgård

The pilot study follows a residential project currently on the drawing board within White Architects Malmö office: Gyllins Trädgård.

Designed to assist White integrate BIM into their working practices, this case project was selected based on that, at time of researching, it was at a suitably developed stage and fulfilled the necessary criteria in terms of participant interest and generic simplicity to implement and test the results of a BIM process centred on an effort to standardise and control information exchange.

At Gyllins Trädgård MKB Fastighets AB plans to build 87 residential units for rent within 9 buildings of 2 to 4 storeys. The project will include 2, 3 and 4 room apartments between 62 and 95 m². MKB, have provided the project consultants with a CAD-coordination manual which stipulates the client's expectations with regards to the use of 3D design tools and for some of the design team members it is the first occasion of working with 3D coordinated models.

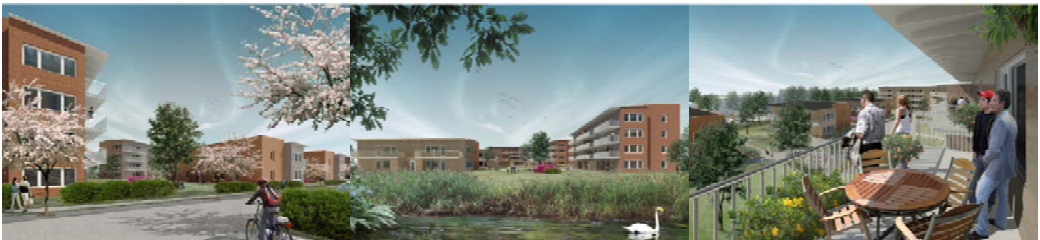


Figure 1: Gyllins Trädgård - Marketing Images (White Architects)

4.2 The buildingSMART alliance™ BIM Project Execution Planning Guide & Gyllins Trädgård Project

The BIM guide details a method for creating and implementing a structured BIM Project Execution Plan and it is proposed that the principle BIM planning procedures outlined in this document be carried out and applied to the case, tuning requirements to the specific project: Gyllins Trädgård. In doing this, this opens opportunities to push forward the frontier of research in this area and identify what is missing from existing models.

This new BIM protocol allows this pilot project to take off where existing information and guidelines left off and provide a platform to move forward with BIM in earnest in a Swedish context and a sound basis for initial dialog, facilitating a method to responding to a number of information exchange issues. Further local

refinement might identify the conditions necessary for success and the barriers which might limit a full implementation and associated leverage of system benefits.

The guide is well aligned with the scope and purpose of this study and focuses on defining the necessary information exchanges through a step-by-step planning procedure:

1. Define project and team value through the identification of BIM goals and uses.
2. Develop a process which includes tasks supported by BIM along with information exchanges.
3. Develop the information content, level of detail and responsible party for each exchange.

4.3 Concepts to be tested in the pilot study

It is proposed that a number of important key concepts relating to project coordination and information exchange are tested in connection with a live residential project in Sweden. These include a formal method of establishing answers to the basic who?- what?- when?- how?- questions outlined in the problem statement as well as testing the principles of developing a BIM implementation plan while seeking to promote the development of consistency within the industry with organisational concepts that are simple and flexible.

4.4 Step 1: Identify BIM goals and uses

One of the most important steps in the BIM planning process is to clearly define the potential value of BIM on the project and for project team members through defining the overall goals for BIM implementation. These goals could be based on project performance and include items such as reducing the schedule duration, achieving higher field productivity, increasing quality through offsite fabrication, or obtaining important operational data for the facility. Goals may also relate to advancing the capabilities of the project team members, for example, the owner may wish to use the project as a pilot project to illustrate information exchanges between design, construction and operations or a design firm may seek to gain experience in the efficient use of digital design applications. Once the team has defined measurable goals, both from a project perspective and company perspective, then the specific BIM uses on the project can be identified (Anumba et al 2009).

A BIM use is a unique task or procedure on a project which can benefit from the integration of BIM into that process. Several examples of BIM uses include design authoring, 4D modelling, cost estimating, space management and record modelling. The team should identify and prioritize the appropriate BIM uses which they have identified as beneficial to the project.

The BIM guide provides users with template documents to help record and develop their project-specific BIM implementation plans.

4.5 Data collected (Workshop No. 1)

The initial workshop centred around a line of questioning facilitating population of a *BIM Goals* and *BIM Use Analysis* worksheets in connection with Gyllins Trädgård. The purpose of these worksheets is to assist project team members in the development of BIM Goals and the selection of BIM Uses based on project and team characteristics.

The design team identified a number of key BIM goals, each allocated with a priority rating and a potential BIM use. It is essential to identify the specific goals that will provide incentive for implementing BIM on a project basis, with consideration to potential benefits, team competencies and technical resources.

Table 1: Extract from BIM Goals Worksheet - Gyllins Trädgård

Priority (1-3)	Goal Description	Potential BIM Uses
1. Most Important	Value added objectives	
1	Reduce design failures	3D Design Coordination, Quantity Scheduling
3	Optimise building rational	Phase Planning (4D Modelling), Site Utilization Planning
1	Establish early control of areas / spaces / relationships	Area Scheduling, 3D Design Coordination

High priorities are to reduce field conflicts through well coordinated 3D design and to be able to leverage data to deliver and control design parameters such as the accommodation schedule against client

requirements. These goals were readily implemented by the design team through the deployment of 3D parametric design authoring tools and capable staff.

By identifying such goals the design team made a first step in planning for a level of BIM implementation. The definition of project team BIM goals allows individuals to understand each other's contribution and outlines the motivations behind the forthcoming information exchanges.

Next, the identified BIM goals are translated into actual BIM uses. The relationship between BIM goals and uses is interpretive and in which a common understanding and agreement is reached through early collaboration and planning.

With each use that's being considered, at least one responsible party is identified. Building information data should ideally be entered only once during the building or information lifecycle by the most authoritative source. By reviewing and formally agreeing who is responsible for what information, it enables building information to be coordinated by the correct source, allowing that data to maintain optimum value.

Table 2: Extract from BIM Use Analysis - Gyllins Trädgård

BIM Use*	Value to Project	Responsible Party	Value to Resp Party	Capability Rating	Additional Resources / Competencies Required to Implement	Notes	Proceed with Use
	High / Med / Low		High / Med / Low	Scale 1-3 (1 = Low)			YES / NO / MAYBE
				Resources Competency Experience			
3D Design Coordination	High	A	High	3 3 2			Yes
		MEP	High	3 3 2			
		SE	High	1 1 1	Training in Revit required	Revit coordination & 2d dwg	

Through auditing a capability rating against each BIM use, responsible parties make an objective judgement with regards to their resources, competency and experience - in other words their professional ability to carry through the BIM use. Together these parameters lead project teams to decide whether or not to proceed with a proposed BIM use. In the case of Gyllins Trädgård, however, a number of aspirational BIM uses were pursued to test results against traditional methods.

4.6 Appraisal

Through this stage of the planning procedure, value is captured by team members articulating the BIM uses to pursue and developing a common understanding of joint goals. Extracted from the BIM use analysis template the plan includes, the following strategic choices can be evaluated as follows:

- *3D Design Coordination:* Here, utilizing collision control tools together with an iterative process of design refinement a significant step forward in the preparation and delivery of a coordinated design information has been realised (see Figure 2). By mitigating potential field conflicts more effectively in 3D, greater cost certainty can be achieved.
- *Design Authoring:* By using BIM tools to generate a composition of parametric objects, the model creating process ensures proper alignment and facilitates a degree of automatic correction - such as adjusting a wall and window schedule in the event of a window deletion - thus reducing the need to manually manage design changes.
- *Design Reviews:* Regular design team meetings with the model as review platform allowed on-the-spot group design decisions to be made, driving an iterative design process, using data to support solutions.
- *Cost Estimation:* Although not completely BIM automated, cost estimates were carried out at incremental stages with increasing level of detail. Quantities were manually extracted but then checked against the models automatically generated quantity schedules. Confidence is still lacking in the accuracy of BIM quantity and cost data amongst some industry professionals however, efforts to test and compare results should in time address this concern.
- *Digital Fabrication:* Here information for the off-site manufacture of timber trusses was released. Whilst not entirely BIM automated, geometric information was extracted from the BIM and augmented with information that was necessary for the CNC machines to interpret and implement the appropriate

manufacturing operations. Early enquiries to ascertain exactly what information the prefabricator needs for his machines could further streamline this area and mitigate re-work.

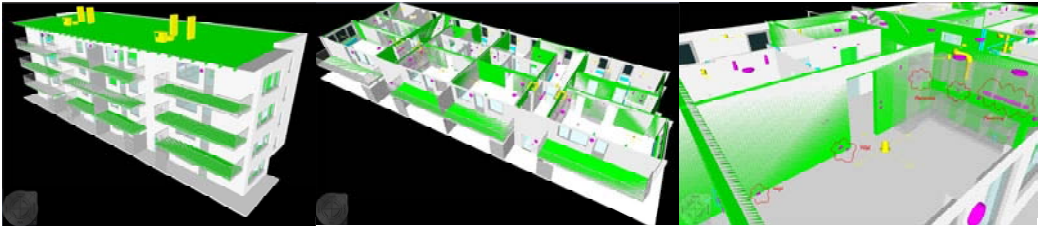


Figure 2: Gyllins Trädgård - Coordination Model (White Architects)

4.7 Step 2: Design BIM project execution process

Once the team has identified the BIM Uses, a process mapping procedure for planning the BIM implementation can be performed. Initially, a high level map showing the sequencing and interaction between the primary BIM Uses on the project is developed. This allows all team members to clearly understand how their work processes interact with the processes performed by other team members. First the high level (Level 1) map is developed (see Figure 3), then more detailed process maps can be added by the team members responsible for each detailed BIM use. The high level map shows how the BIM authoring, energy modelling, and cost estimating, are sequenced and interrelated. The secondary detailed maps records the detailed processes that will be performed by an organization or in some cases several organizations, such as the energy modelling.

Engaging the design team in this process goes some way to determining the 'who' and 'when' questions previously cited.

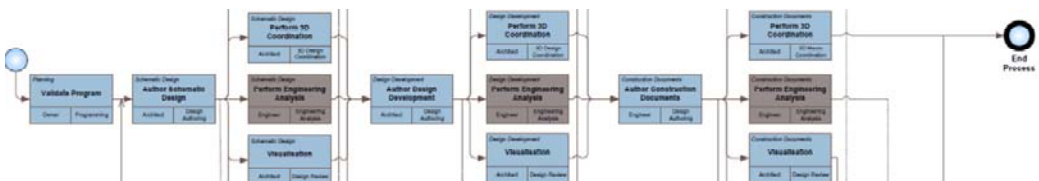
4.8 Data collected (Workshop No.2)

A second workshop was scheduled to record relevant information to facilitate the design of BIM *Execution Process Maps* for Gyllins Trädgård. The overview map below (see Figure 3) shows the relationship of BIM uses which will be employed on the project. This Level 1 process map also contains the high level information exchanges that occur throughout the project. Fundamentally the BIM use work packages or processes develop in information maturity as the task passes from *schematic design* through to *construction documents*.

The BIM uses are arranged according to project sequence, helping to communicate the phasing of each BIM use and define implementation sequence. Responsible parties for defining the information required to implement the process as well as the information produced by the process are identified and graphically notated.

Detailed BIM Use Process Maps are created for each identified BIM Use to clearly define the sequence of various processes to be performed. These maps also identify the responsible parties for each process, reference information content, and the information exchanges which will be created and shared with other processes. Here, beyond BIM process sequencing, dependencies between the processes are defined by considering the connections between processes. Gateways provide opportunity to represent decisions, design iterations or quality control checks.

Figure 3: Extract from BIM Execution Process Map - Gyllins Trädgård - Level 1: BIM Execution Planning Process



4.9 Appraisal

This process aims to determine which party is the best authoritative source for a particular piece of information, and what pieces of information each source or design participant needs to provide to others to enable those third parties to perform their tasks. The Level 1 process map allows team members to map what it does, what information it handles, and whether it is the optimum responsible party for that information.

By mapping BIM uses, processes and ultimately information exchanges in this way, it enables the design participants to:

- Appreciate new types of information a team member may be able to share that might be useful to others;
- Which information, provided by others, could help a team member perform its function better;
- How information is used in each team member's business processes and how it flows through their business systems;
- Focus on delivery of real services thus reducing or eliminating low-value data entry tasks;
- Opportunities to eliminate overlaps, redundancies or abortive work;
- Identify information exchanges that accelerate iterative workflow cycles.

The process of simply entering into dialogue and mapping BIM uses and associated work flow can help an organisation discover an ability to exchange information internally among different software applications that it previously didn't know, or that information created for previous projects may now be exploited more effectively for future projects.

The fundamental advantage of agreeing and recording such procedures is that it enables the team members to understand each other's tasks and work towards common goals that are often interdependent on information supplied by each other.

4.10 Step 3: Define Information Exchange Requirements

Once the appropriate process maps have been developed, the information exchanges which occur between the project participants can be identified. It is important for the team members, in particular the author and receiver for each information exchange transaction, to understand the information content.

This information content for the exchange is defined in the Information Exchange table. Here, consultants develop a chart mapping information exchange content, level of detail and responsible party for each exchange. This procedure identifies the vital information required to implement each BIM Use as defined previously.

The purpose here is to document the information that must be passed from one organization (responsible for a BIM use) to enable another to progress with their business process. When information is delivered in the form and quality expected, an efficient workflow is achieved.

In order for meaningful and enabling information to flow, a number of key factors need to be considered:

- The format of the information (type);
- A description of the concepts used / information to be exchange (what) and when;
- A common understanding of each design team member's information needs.

Once defined, an information exchange matrix can form the basis for parties' data interchange, allowing the information to be treated as an asset enabling efficient BIM processes and regulating information sharing between design team participants.

4.11 Data Collected (Workshop No.3)

A third workshop enabled collection of data to complete the BIM plan's Information Exchange Worksheet. This worksheet was developed to aid the project team to define the information required to implement each BIM Use with maximum efficiency. The mission here is to record information delivery expectations against a model element breakdown (the intention is that this should concur with the local classification system) through the scheme design, design development and construction documents stages for each BIM use.

Parties can share a strategic insight into the content, format, responsibility and timing of information exchange enabling optimised efficiency in data exchange through the design period.

Table 3: Extract from Information Exchange Worksheet - Gyllins Trädgård

BIM Use Title	Design Authoring (Schematic Design)			Cost Estimation			3D Coordination			Design Reviews			Energy Analysis			Design Authoring (Design Development)				
Project Phase	Design			Design			Design			Design Reviews			Design			Design				
Time of Exchange (SD, DD, CD, Construction)	SD			SD			SD			SD			SD			SD				
Responsible Party (Information Receiver)	A, SE, MEP			Cost Consultant			A, SE, MEP			A, SE, MEP			Energy Consultant			A, SE, MEP				
Receiver File Format	Revit *.rvt, Acad *.dwg						Navisworks *.nwd			Navisworks *.nwd			Acad *.dwg			Revit *.rvt, Acad *.dwg				
Application & Version	Revit V.10, Acad, MagiCad						Navisworks V.10			Navisworks, PowerP			VIP *			Revit V.10, Acad, MagiCad				
Model Element Breakdown																				
		Info	Resp Party	Additional Information	Info	Resp Party	Notes	Info	Resp Party	Notes	Info	Resp Party	Notes	Info	Resp Party	Additional Information	Info	Resp Party	Additional Information	
SUBSTRUCTURE																				
Foundations																				
	Standard Foundations	A	A/SE		A	A/SE		A	A/SE		A	A/SE						B	A/SE	
	Special Foundations	A	A/SE		A	A/SE		A	A/SE		A	A/SE						B	A/SE	
	Slab on Grade	A	A/SE		A	A/SE		A	A/SE		A	A/SE						B	A/SE	

4.12 Information Levels

Key to aligning data exchange expectations within project teams is a system for describing information content. In Denmark (bips 2006) and Australia (CRC 2009) similar systems suggesting a hierarchy of information development levels have been articulated. Both systems suggest 7 development information levels ranging from brief to post construction. Representing a simple form of information maturity, an abbreviated information levels code can identify information maturity expectations.

4.13 Appraisal

In a scenario of a heavily laden information model being present, defining information exchanges becomes a critical operation to enable one to distinguish the wood from the trees and avoid laborious and time-wasting filtering exercises. A common frustration in practice occurs when information supplied by another is not what was expected or is of insufficient quantity or quality to carry out the immediate task without additional or subtractive operations. Every element of a project does not need to be present to be valuable therefore, it is important to only define the model contents that are necessary to implement for each BIM use.

If a receiver of information wants to be sure he or she can utilize the information received, the sender and receiver need to agree on which information to exchange. For example, an architect needs to be sure that he receives information from the structural engineer as regards which walls and columns are structurally load-bearing. Similarly, the structural engineer needs to know the use characteristic of the enclosures in order to calculate the correct design loads.

For BIM to be implemented successfully, it is critical that team members consider the future use of the information that they are developing - when the architect adds a wall to the BIM, that wall may carry information regarding the material quantities, structural and thermal properties. The architect needs to know in what way this information will be used in the future. The future use of this data can impact the methods used to develop the model content, or identify quality control issues related to the data accuracy for subsequent tasks relying on the information.

5.0 CONCLUDING DISCUSSION

The buildingSMART Alliance's BIM guide presents a valuable method of determining important prerequisites for effective BIM implementation. Together the BIM plan's planning procedures enable team members to gain a strategic insight into the who?- what?- when?- how?- questions relating to information exchange. The process facilitates a rational of continuous improvement by enabling teams to identify areas where processes are suboptimal and offers meaningful and flexible direction to achieving BIM integration and scope to identify opportunities for standardisation.

It can be observed that some technologies are not being used to their full advantage but enthusiasm amongst design consultants has pushed teams to experiment in parallel with traditional methods in a hunt for confirmation of usefulness.

However, what is problematic is that often project teams have varying levels of competence and willingness to partake in an iterative design process where fees are spent before they're earned. With new processes comes new relationships and organisations, firms cannot afford to view their contribution in isolation. At times it can be a struggle to obtain a consistent information level across all disciplines in a similar time frame but parallel processes are enabling a higher quality of design service to emerge which more and more clients are demanding.

One thing is clear, however, and that is that the participants all recognise the benefit of working in close collaboration from the early stages through design development. The possibility to make early and informed

decisions through the use of technology to leverage a high level of quality information at the right time in the process has enormous potential to improve the state of the construction industry by injecting greater certainty.

It was noted that the drive behind BIM on this project has come from the client who has supplied a CAD-Manual detailing a base contractual requirement to produce 3D coordinated models for delivery to the contractor. There is the suggestion that many design consultants in Sweden are committed to implementing BIM since it is being demanded by more powerful actors. They see BIM as the means of addressing design challenges with which they are now faced. They believe that if they do not accept this challenge now, they will be overtaken by their competitors.

White Architects face a transition period between old practices and new while still meeting day to day programme requirements and deadlines. There is an inherent element of risk in changing practice working methods, however, such pioneers are beginning to realize efficiency gains. Although the extent of BIM usage here was somewhat immature, the focus is on perfecting the areas where BIM implementation is successful and where results are trusted. Secondary BIM possibilities are being investigated in parallel, and with experience on the rise, confidence should follow and enable extended uses and greater efficiencies to be leveraged.

As more industry professionals gain a greater understanding of the value of building information created not just through the design phase but through the whole building life-cycle, and learn to manage their own information accordingly, more will be able and willing to engage in value-added information exchange.

This process of attempting to define information exchanges for each relevant BIM use is closely tied to the development of the Information Delivery Manual (IDM) and Model View Definition (MVD) in which exactly which information is to be exchanged in each exchange scenario is specified (BuildingSmart 2010). If developed into MVDs the exchange requirements should be assembled into re-useable concepts mapped to specific objects, properties and relationships present.

The conclusion of this preliminary study naturally leads to the development of a more extensive study of information deliveries and standardisation needs using BIM to enable findings to be generalisable and conclusive.

Acknowledgments

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Paper #2:

A BIM-Info Delivery Protocol

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A BIM-Info Delivery Protocol

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Abstract

Today, with many of the technological matters of integrated information management resolved (perhaps excluding the matter of interoperability), defining the content and status of BIM information deliveries remains both a practical and theoretical problem.

New BIM tools and new design processes and procedures have led to a certain confusion of what information is needed when for particular BIM uses. This paper seeks to explore and enable a method of defining the content of model information deliverables through a review of 2 key primary specific BIM uses: *3d Design Coordination* and *Early Energy Appraisal* through an analysis of practical application.

The scope of this study is limited to a review of information flow within residential projects in a Swedish context and looks at two case projects with a view to identifying and establishing a common definition of the key BIM objects and properties necessary for particular tasks.

The key deliverable from this study is the BIM-Info Delivery Protocol (IDP) which attempts to align consultant BIM-Info delivery expectations and represents a tangible solution to assist consultant disciplines manage BIM-Info. Concluding reflections consider the positioning of the IDP relative to the ongoing development of IDMs / MVDs and highlight the key constituent parameters of an Information Delivery Specification (IDS).

Keywords: BIM, Building Information Modelling, information exchange, model information content.

1. Introduction

1.1 Background to Study

The context of the study is directed toward the Swedish Design-Construct-Operate (DCO) sector where the concept of *Leveransspecifikationer* (Delivery Specifications) is suggested within the national guidelines for digital information management: *Bygghandlingar 90 – Byggsektorns Rekommendationer för Redovisning av Byggprojekt – Digitala Leveranser för Bygg och Förvaltning* (Swedish Standards Institute, 2008). These guidelines recommend the use of delivery specifications to accompany exchanges in digital information at all stages of the design, construct and operate process. However, there is a lack of concrete advice on how to develop information delivery specifications for defining and recording BIM-Info content in connection to or supporting a project based strategic BIM Implementation Plan.

Information is not lacking, however, practical experience in moving forward with BIM beyond office boundaries in Sweden still is in its infancy and there is hitherto an absence of developed examples of delivery specifications to accompany national standards.

1.2 Goals and Research Questions

This study has two goals. The first is to explore and enable a method of defining the content of model information deliverables through a review of 2 key primary specific BIM uses: *3d Design Coordination* and *Early Energy Appraisal* through an analysis of practical applications. The second is to design an associated process that ensures integration of information deliveries into a project plan, thereby securing greater certainty and efficiency of information exchanges.

The central research questions for these goals are as follows:

- ✦ How could BIM-Info delivery content be articulated in a commonly understood manner on a project basis?
- ✦ Could a standard matrix be established that can be used for various BIM-Uses at various project stages that would help align information delivery expectations?

To answer these research questions five sub questions need to be answered:

- ✦ What BIM-Info is needed at what time to enable efficient BIM Discipline Authoring toward e.g., rapid 3d Design Coordination at Design Development Stage?
- ✦ What BIM-Info is not needed? – Clarity is needed on what BIM-Info is not relevant at particular stages.
- ✦ What level of detail is needed to carry out BIM-Uses at various stages?
- ✦ Is there a logical information order?
- ✦ What is the logical information order of authoring BIM-Info for early Energy Analysis when it comes to generating BIM objects?

1.3 Problem Status

Whilst organisations such as the buildingSMART Alliance are investing considerable resources towards developing AEC industry standardization in information exchanges, until understanding, control and trust can be gained in the use of IFC, IDM and MVD by DCO participants, a simpler system of describing information content requirements is essential to BIM implementation today on a consultant practice level.

Without a straightforward way of creating project specific IDM's, a clear understanding of the content of MVD's, and the ability to control information flow through such methods, trust may wither and die. Thus the driver for this study: the urgent need for a simple, user-friendly method of describing, in a commonly understood way, information deliverables.

1.4 Hypothesis

Perhaps a simpler method of generating IDM's and MVD's using commonly available tools within organisations would have greater mileage than those developed by external agents. Here it is conjectured that, as a valid alternative, BIM-Info Deliveries developed by architects and engineers for architects and engineers may offer the control, confidence and simplicity necessary for effective information exchange success.

In order for industry professionals to get the best out of BIM tools and work efficiently, one needs a big picture understanding of information need, honing individual tools and processes towards greater efficiency and certainty. Key to doing this is a thorough documentation of one's own business processes – use of a BIM-Info Deliveries Protocol as part of a BIM-Implementation Plan may offer an immediate and tangible solution.

2. METHODS

2.1 Research Design

The research design has been flexible from the start to enable the framework of reference to emerge during the study. Literature review - including national standards guidelines and industry press – together with consultant interviews and discussions revealed a real need for the development of BIM-Information delivery specifications to support cross-discipline communication and downstream use of data. To move forward, two case projects were identified. The first to enable a closer examination of the issues involved. The second to test a protocol proposal and enable categorization the building parts and level of detail required for a set exchanges against a specific BIM-Use.

The case study's strength is its ability to deal with a full variety of evidence - documents, interviews, and observation - beyond what might be available through other research approaches (Yin 2003). Here, two important sources of evidence are: direct observation and systematic interviewing.

Through its natural setting, the case study provides an ideal practical real-life context and a suitable grounded platform to consider and test strategic decisions with regard to information exchanges thereby creating an opportunity to introduce a move towards a greater clarity of purpose and improved efficiency in information sharing.

2.2 Data Collection and Case Description

The collection of empirical material has been assembled to firstly facilitate a deeper understanding of the circumstances and context of the information exchanges necessary to implement the said BIM-Uses and secondly study the BIM-Content to be exchanged at object-level.

To meet these objectives a series of design coordination workshops were carried out in connection with a (real world) residential case study project (Koggens Gränd) facilitating collection of empirical data, together with the generation and examination of a controlled experimental model (KonsultHus).

The known characteristics of this first case fit well with the opportunities to break new ground and strive towards improvements in information management and uncovered a raft of issues to address. The second case enabled the extraction of more detailed information to populate the delivery specification.

2.3 Case #1: Koggens Gränd - Malmö's first owner-occupier flats

Located in the Västra Hamnen area, Malmö, Koggens Gränd is an innovative new residential block with occupancy expected through 2012. As part of a larger development incorporated in the regeneration of Västra Hamnen the scheme presents 31 owner-occupier flats, between 45-72m².

Prior to May 1, 2009 in Sweden it was not authorized to build owner-occupier flats as new build or through renovation of existing buildings. Koggens Gränd represents one of Sweden's first residential building containing owner-occupier flatted units on a larger scale.



Figure 1: Koggens Gränd – Source: White Arkitekter

The researcher followed this project through its early stages, recording matters relating to 3D Design Coordination and collected further empirical data relating to requirements and procedures for this BIM-Use. In addition, common current practice methodologies were documented with a view to identify key issues to address. Through this case study, a thorough examination of the common issues hindering work-flow of 3D Design Coordination and early Energy Analysis operations was enabled.

2.4 Case #2: KonsultHus - An Experimental Coordination Model

Empirical data reflecting the results from this experimental model, which was developed and used by the author for this study, has enabled collection of further, more detailed information, eliminating unwanted variables, and facilitating a more precise examination of objects and properties required for 3D Design Coordination. 3D Design Coordination implies close collaboration and, on complicated projects - a frenzy of information exchange. For this reason it is critical to record and optimise information flow for this BIM-Use. Here it was examined what BIM-Info one needs to share with each other to allow for example:

- ✦ the MEP consultant to proceed with design for plant requirements, ventilation duct sizing and routes, plumbing fixtures and pipe routes, drainage integration, incoming service routes and;
- ✦ the Structural consultant to proceed with design for the foundations and structural frame.

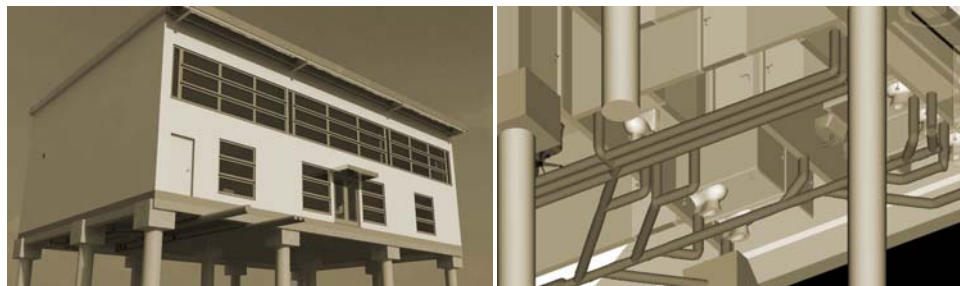


Figure 2: KonsultHus – An Experimental Coordination Model

It is clear that in order to optimise design information production and flow, parties must have at least a modest understanding of each other's information needs and, moreover; if you are not specific about the information you need, how can you be certain you'll get it?

Complaints of holding each other up because of lack of design information, or deliberately holding back design contributions until 'the architect has frozen the design', no longer washes with today's parallel BIM processes and collaborative design environment. Through this case study, an experimental exchange protocol was tested to help monitor the creation, distribution and timing of discipline BIM objects on a need-to-know basis.

3.0 A STATE OF THE ART REVIEW

Many studies have been carried out to investigate, test and report on process development in the domain of BIM, not least information exchange and collaboration. Furthermore many studies still report difficulties and barriers both technical (such as interoperability) and non-technical (such as organisational and team communication). (Pazlar & Turk 2008) for example reports *data distortion and IFC interfaces not working as expected*, (Pfitzner et al 2010) reports on barriers relating *project organisation and commitment among project team members to collaborate*.

Much of the existing research focuses on identifying existing barriers, this paper concentrates on developing a simple tool that may help overcome certain communication barriers.

Here in Sweden, particular hindrances to efficient information exchange in the context of BIM-Uses could be said to reside in under-developed national guidelines (Bygghandlingar 90) and the immaturities of the technical initiatives of the buildingSMART Alliance (including IFC, IDM's and MVD's).

3.1 Bygghandlingar 90 & Delivery Specifications

This publication (Bygghandlingar 90, 2008), represents Sweden's chief guidelines for delivering digital information in connection with construction projects and is a valuable source of logical recommendations for managing building information in an organized and careful manner. However, it does not represent a BIM Standard and requires some development in a number of areas including that of BIM-Info Delivery Specifications. The output from this study aims to provide practitioners with a useable tool to address this deficiency and help the industry move towards procedural standardization.

3.2 buildingSMART Alliance Initiatives

Among the foundational standardization efforts of the buildingSMART alliance and its worldwide counterparts are the Information Delivery Manuals (IDMs) and Model View Definitions (MVDs). These are examples of the sector's collective recognition that better information is needed to support the development of better tools now emerging to deliver construction projects (Smith & Tardif 2008). Technologies such as IDM and MVD are intended to help identify exactly what that information is by defining, for example, a model definition view for automated code checking and the information that must be included to generate that view. However, this is work in progress and is still a long way off being available for all DCO participants; as is the full capabilities of IFC.

4.0 Implementation

4.1 BIM-Info: A Consultant Perspective

Whilst many consultants are demonstrating a strong interest in BIM there is a possible lack of practical knowledge in applying current technology and leveraging the much bragged about benefits of BIM. Other research (Gu & London 2010) has revealed that DCO participant concerns primarily focus on practice, process and technical related issues. Here, through the events and discoveries revealed in particular through case #1 within this study, the following observations are highlighted:

- ✦ Significant uncertainty exists amongst design team participant as to exactly what information to provide for each 3D Design Coordination Meeting.
- ✦ Because of a lack of clarity, there was certain carelessness in providing quality BIM-Info.
- ✦ Quality checks on BIM-Info deliveries appear to be missing or inadequate prior to issue.
- ✦ Apprehensions exist in delivering incomplete work or work in progress - suggesting a need for an additional BIM-Info status classification: WIP (work in progress).
- ✦ Some design participants were reluctant to engage in design work and contribute to a developing design process prior to the Architects layout being 'frozen'.
- ✦ Limited time / budget for design changes or iterations for specialist design participants - instead of productivity gains being fruitfully utilised to optimise the design, it presented an opportunity for some consultant organisations to simply take on more work.
- ✦ Among all participant disciplines, the architect was the most active member in attempting to resolve communication issues and align design team expectations in terms of information delivery and content requirements.
- ✦ Digital communication and information storage was established through a web portal to a project server. This enabled logging of all communications and a database for all current and live information.
- ✦ Folders were set up with associated access rights for each discipline enabling design participants to upload information in a commonly understood fashion.

4.1.2 Key Issues

The emerging key issues that can be identified in connection with the above observations can be categorized and summarized as follows:

4.1.2.1 Practice issues:

- ✦ Whilst project team members display enthusiasm and general interest for implementing BIM, there appears to be a lack of a common understanding of what it entails not least in terms of BIM-Info deliverables.
- ✦ Time commitment in the early stages presented difficulties and frustration, suggesting a resistance to change or flawed time planning.
- ✦ Some localised competence issues in the use of 3D BIM authoring tools / lack of thoroughness in delivering quality information.

4.1.2.2 Process issues:

- ✦ Willingness to collaborate and contribute towards the project design on the same information level (LOD) as others within the same timeframe was problematic, suggesting the need for stronger culture of BIM Implementation Planning together with a method of clearly articulating BIM-Info Deliveries.

- ✦ Quality Control and validation of delivered BIM-Info was often left to the receiver to sort out - leading to down time for file clean-ups, deletion of duplicate objects etc.

4.1.2.3 Technical Issues:

- ✦ Naturally, not all design participants used to same BIM tools for model authoring. The transfer of MEP BIM-Info into the multi-disciplinary model for collision control presented problems. Here a lack of trust in data integrity emerged. The completeness and accuracy of 3D models remain a major concern for the design team.

4.2 Difficulties

In addition, derived from the case #1 design team meeting observations and case #2 practical experiments, a number of specific difficulties were identified relating specifically to 3D Design Coordination and early Energy Analysis.

3D Design Coordination – Common Problems:

- ✦ 1000's of collisions identified late in the design process with little opportunity to correct or solve them.
- ✦ Early agreement on tolerance levels is critical including clearance between own discipline objects and other discipline objects.
- ✦ Accountability for the maintenance and coordination of objects and properties must be clear.
- ✦ Agreement of procedure for managing changes to the design required to mitigate or remove hard, clearance or duplication collisions.
- ✦ Missing voids - Lack of accounting for voids for services including type, purpose, discipline, responsibility for correctness.
- ✦ Where objects are within the domain of both architect and structural engineer and in addition require input from the services engineers with regards holes etc, difficulties can arise through duplication.

Energy Analysis – Common Problems:

- ✦ No clear direction of what objects and properties are necessary for which analysis at what stage.
- ✦ Tendency not to focus on authoring the right information at the right time.
- ✦ Analysis carried out too late to have any pro-active impact on the design.
- ✦ Analysis results miss-interpreted.
- ✦ Analysis carried out by external consultant at a single point in time / results not acted on.
- ✦ No clear agreement or procedure for managing changes to the design to reduce energy consumption.
- ✦ Analysis carried out to confirm suspicions instead of to inform design and drive toward optimised solution.
- ✦ Major change in design instructed, focus on energy diminished or extinguished.

This evidence suggests that action is required to address these uncertainties and communication malfunctions. What is needed to combat these failures is clear and user-friendly articulation of process, what it involves and what information needs to be delivered by each party, when.

4.3 BIM-Info Deliveries

As a valid alternative to the rather cumbersome and overly complicated MVD's being developed by the building SMART Alliance and others, this paper offers a simple method of defining, on a project basis, information deliveries for specific BIM Uses.

It has been suggested that if the industry is to move forward with BIM implementation, firms must focus on perfecting what they can deliver (Jernigan 2008). Initially this means reaching for the low hanging fruit such as 3D Design Coordination (through use of collision control tools) and early Energy Analysis (through use of built-in or associated energy simulation tools).

Both these BIM uses instantly add value to the DCO process and product and can be considered strategic, straightforward targets for consultant organisations to master in an efficient manner. What is problematic, however, is for team members to arrive at the same place at the same time with regards to BIM-Info quality and completeness. This is particularly critical in the context of the successful execution of various BIM-Uses including 3D Design Coordination. Project direction and information flow often meanders left and right of an efficient path resulting in frustration, loss of momentum behind value-adding processes, and often considerable time wasted.

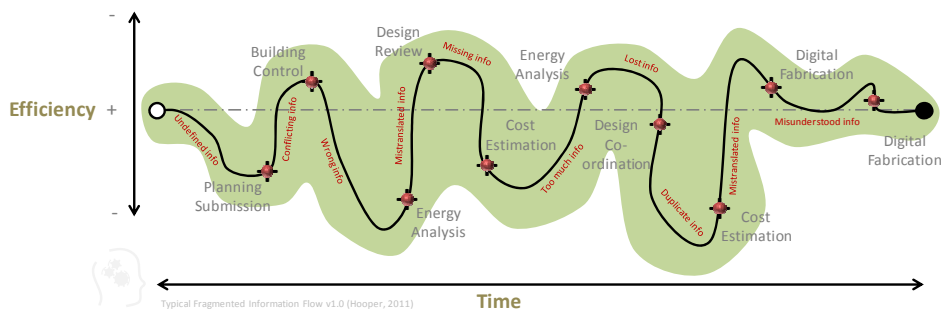


Figure 4: Information Flow – Traditional

Laying down considerable time and effort to carry out what should be routine tasks is a major concern to DCO players. Those who are bearing the pain of BIM implementation are struggling to leverage the benefits of added service and increased productivity as a result of downtime consumed by manually filtering, editing, adding, deleting, finding out if its valid and re-working building design information for what in theory should be sequential BIM Uses.

By encouraging all design participants to engage in work flow design and actively be aware of each other's information needs, the use of a BIM-Info Protocol has the potential to straighten work flow and increase the accuracy and efficiency of information exchange. Coordination efforts here requires time but lays the foundation for greater gains through the process.

Once organisations have succeeded and gained confidence in recording, purposefully designing and optimising their work-flows with attention to information exchange, project standards can develop into office standards and further to a National Standard. Within the sphere of information exchange, this study endeavours to organise and present key prerequisites necessary to set in motion a system design converging on standardisation.

So far this element of business practice within the AEC consultant sphere has been either largely missing or out of date. The figure below suggests a process which might help DCO

participants move forward in earnest and articulating BIM-Info content with a view to optimising information flow and reducing exchange failures.

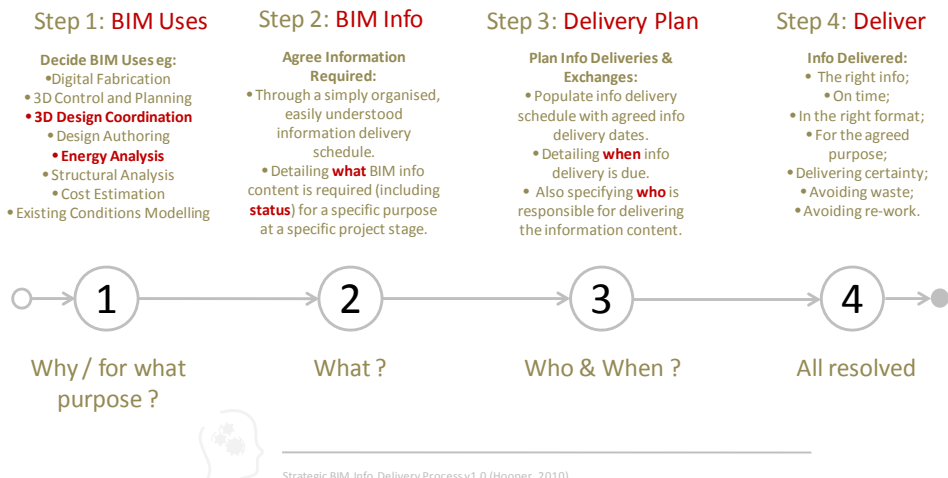


Figure 5: Strategic BIM-Info Delivery Process

5.0 BIM-INFO DELIVERY PROTOCOL (IDP)

Emerging from the observations and results revealed through discussions and experiments, the BIM-Info Delivery Protocol (IDP) is presented below as a sequence of pedagogical steps designed to respond to the research questions.

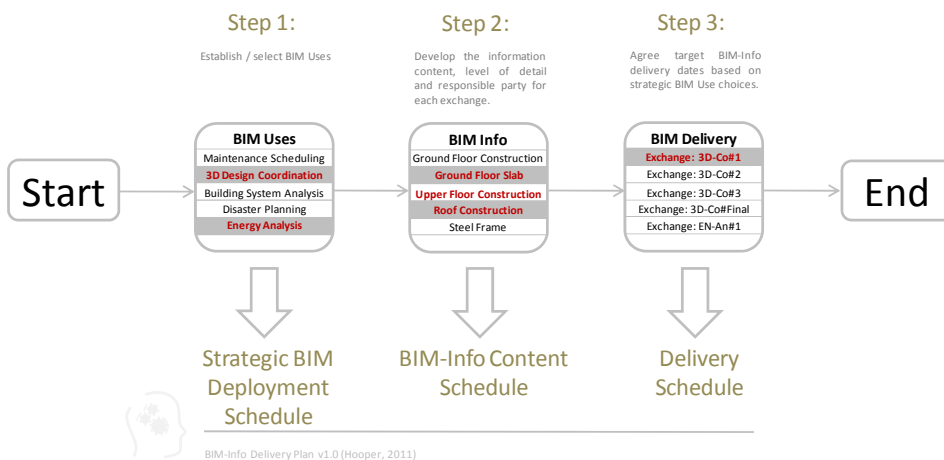


Figure 6: BIM-Info Delivery Protocol (IDP)

5.1 Step 1: BIM-Uses

The buildingSMART Alliance’s Building Information Modelling Execution Planning Guide (Anumba et al 2009) suggests a list of 25 typical BIM Uses including of course 3D Design Coordination and Energy Analysis. It naturally follows that teams must establish at the outset

the strategic BIM-Uses they wish to deploy on a project specific basis. The decision to implement a BIM-Use must be based on resources, competency and anticipated value to the project (Anumba et al 2009). Against each BIM-Use members should consider and articulate the timing of such activities through the BIM-Authoring stages to enable focus on imminent information demands and optimize information flow. The figure below illustrates how this might be articulated whilst enabling efficient implementation.

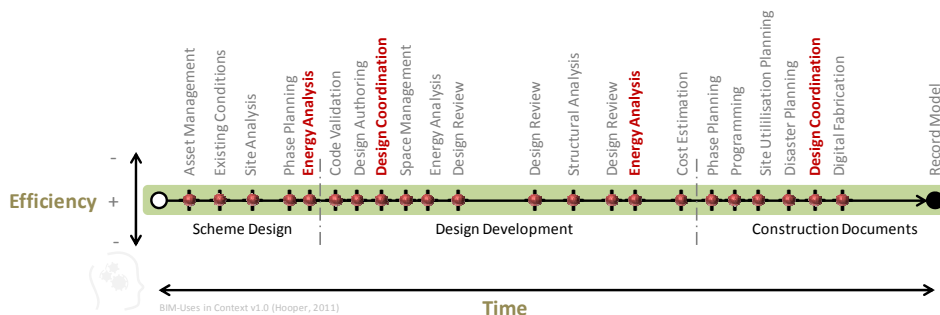


Figure 7: BIM-Uses in context

Often overlooked, there is common business sense to the idea that, if certain design information can be supplied at right time, then its value to the project can be optimized. BIM-Uses should be selected for the right reasons – as drivers to the process and to help provide the data to support strategic decisions along the way.

5.2 Step 2: BIM-Info

Here a definition of the model information content for strategic BIM implementation is articulated through scheduling the key objects with associated level of detail and responsible party. In this instance a BIM-Info Delivery Specification (IDS) template has been developed to express the information content and exchanges necessary to carry out and efficiently implement BIM-Use: 3D-Co (3D Design Coordination).

The main tools used to develop this schedule where Autodesk Revit Architecture together with Microsoft Excel. An important aspect of this study and resultant product is that by utilising industry standard tools and readily understood categories and classifications, consultants can maintain control of model content definitions and thereby build and retain trust in the exchange processes they create.

5.2.1 Identifying BIM Objects & Properties for Strategic BIM Uses

The AIA (AIA 2008) amongst others has defined the concept of Levels of Detail (LOD) described through a sliding scale of LOD 100 – 500. In essence, the levels can be summaries as follows:

- ✦ LOD 100: Conceptual
- ✦ LOD 200: Approximate geometry
- ✦ LOD 300: Precise geometry
- ✦ LOD 400: Fabrication
- ✦ LOD 500: As-built

The LOD concept, established through the AIA's E202 Protocol published 2008 is now starting to be adopted throughout the world (Statsbygg 2011). This standard together with an appropriate building element classification can be deployed to identify the BIM-Info required for specific tasks, however, in practice additional BIM objects and properties need to be identified out with the scope of most building classification systems. For this reason it is necessary to facilitate flexibility in BIM-Info scheduling and include, where appropriate, scope to articulate request for data such as:

- | | | | |
|----------------------------|----------------------|-------------------|--------------|
| Project Information | Project Units | Annotation | Other |
| ✦Project Issue Date | ✦Length | ✦Location | ✦Voids |
| ✦Project Status | ✦Area | ✦Coordinates | ✦Holes |
| ✦Info Status | ✦Volume | ✦Position | |
| ✦Client Name | ✦Angle | ✦Grids | |
| ✦Project Address | ✦Slope | ✦Levels | |
| ✦Project Name | ✦Currency | ✦Rooms | |
| ✦Project Number | | ✦Areas | |
| | | ✦Zones | |

The need for extra BIM object classifications beyond those to be found in national classification systems is clear. The above categories, identified through the authoring process of the KonsultHus case project, have been included in the BIM-Info Delivery Specification to enable transfer of that information between consultant disciplines in a clear and comprehensive way.

BIM Information Delivery Specifications - 3D Design Coordination										
BIM-Info	Responsible	Notes	BIM User: 3D Design Coordination				BIM User: 3D Design Coordination			
			Level of Detail	Info Author	Info Reciever	Format	Level of Detail	Info Author	Info Reciever	Format
Information										
Location	Arch		X - Confirmed	Arch	Struct & MEP	*.rvt				
Coordinates	Arch		X - Confirmed	Arch	Struct & MEP	*.rvt				
Position	Arch		X - Confirmed	Arch	Struct & MEP	*.rvt				
Grids	Arch		X - LOD 200	Arch	Struct & MEP	*.rvt	X - LOD 200	Struct	Arch & MEP	*.rvt
Levels	Arch		X - LOD 200	Arch	Struct & MEP	*.rvt	X - LOD 200	Struct	Arch & MEP	*.rvt
Rooms	Arch		X - LOD 200	Arch	Struct & MEP	*.rvt				
Areas	Arch		X - LOD 200	Arch	Struct & MEP	*.rvt				
Zones	Arch		X - LOD 200	Arch	Struct & MEP	*.rvt				
SUBSTRUCTURE										
Foundations										
Standard Strip Foundations	Struct		X - LOD 200	Arch	Struct & MEP	*.rvt	X - LOD 200	Struct	Arch & MEP	*.rvt
Special Foundations										
Slab Foundations										
Pile Foundations	Struct		X - LOD 200	Arch	Struct & MEP	*.rvt	X - LOD 200	Struct	Arch & MEP	*.rvt

Figure 8: Extract from BIM-Info Delivery Specifications (IDS)

An innovative feature, still under development, is the possibility of automating the extraction of requested BIM-Info through an XML schema, enable through the IDS spreadsheet, thus eliminating manual filtering and if perfected, scope for error. A prerequisite of this novelty is a thorough and complete tagging of objects to the utilized building components classification.

Information	Responsible	Notes	Level of Detail	Info Author	Info Reciever	Format	Level of Detail	Info Author	Info Reciever	Format
Construction Information	Arch		X - LOD 200	Arch	Struct & MEP	*.rvt				
Engineering Information	Arch		X - LOD 200	Arch	Struct & MEP	*.rvt				
Record Information	Arch		X - LOD 200	Arch	Struct & MEP	*.rvt				
Link to Model: Holmes Office - Architecture.rvt										
Link to Model: Holmes Office - Structure.rvt										
Extract Info Content From Project Server						Extract Info Content From Project Server				

Figure 9: BIM-Info Content Extraction

5.3 Step 3: BIM-Delivery

Registry of BIM-Info exchanges can be readily recorded and communicated through project networks in accordance with the delivery schedule. However, often neglected is a sub-process of quality control. This is necessary more than ever – not least to demonstrate due diligence – but to ensure the content of BIM-Info Deliveries match with the general expectations of the project team as articulated in the BIM-Info Delivery Specification

schedule. This process is essential to eliminate rework for receivers and puts the onus on the supplier to ensure the contents is what it says it is.

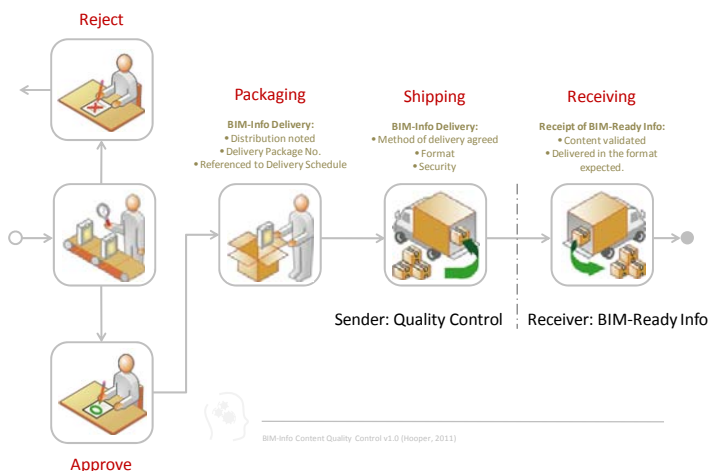


Figure 10: BIM-Info Content Quality Control Measures

6.0 Conclusions

6.1 Summary of Main Findings

The key deliverable from this study is the BIM-Info Delivery Protocol (IDP) which attempts, through use of straight-forward and easy to use tools, to align consultant BIM-Info delivery expectations and represents a development of the concept behind Leveranssspecifikationer mentioned but not substantiated in Bygghandlingar 90.

By recording information flow properly we can better understand each other’s information needs and reduce the risk for misunderstanding. If handled optimally BIM-Info can significantly enhance the quality of the product and safeguard the success of project. A clear and commonly understood picture of the BIM-Info Deliveries through establishing a project standard BIM-Info Delivery Specification offers a tangible solution to help consultant disciplines manage BIM-Info.

To add maximum value to the project, the timing and content of BIM authorship is critical. By articulating planned BIM-Uses, the necessary BIM-Info needed to carry out these Uses together with target BIM-Delivery dates; project teams can more readily focus on the strategic task in hand and help each other to deliver the intended result in an efficient manner.

The BIM-Info Delivery Protocol (IDP) is a compelling tool for use in the evolving world of virtual design and construction teams and can be used as a basis for a BIM Management Plan. However, industry reference-group feedback has suggested a number of limiting factors including that “it would be an additional burden, indeed laborious, to fill out the IDS when projects are already on a tight time schedule and budget. If teams cannot directly see the positive effects of using such a protocol, it may be difficult to achieve widespread uptake.” This protocol represents a tool for improvement, a first step could be to first record one’s own strategic information requirements, recognition of this together with patience may prove to be prerequisites.

6.2 Positioning of BIM-Info Delivery Protocol (IDP) v. IDM & MVD

On reflecting on the positioning of the BIM-Info Delivery Protocol in relation to IDM and MVD a number of discrete characteristics can be identified:

- ✦ The IDP represents a ready-to-use tool for communicating and aligning information exchange expectations, independent of software application.
- ✦ The development of IDM and MVD's have yet to reach maturity and are dependent upon the complete and successful implementation of the IFC model within the BIM authoring software applications – this has yet to be realised and there is resistance within a number of the key software suppliers to do so.
- ✦ The principle difference in methodology between the IDP and building SMART's IDM/MVD is that building SMART's purpose is to solve interoperability. Whilst this is a crucial goal, the IDP method is needed as a first step and the results can be used as input to the ongoing work with IDM's and MVD's.
- ✦ The IDP is orientated towards the Architects and Engineers who represent the key members of the model authoring team.
- ✦ Whilst IDM & MVD require in-depth technical IT and systems knowledge, often outside the scope of expertise of many DCO project participants.
- ✦ The IDP may provide the industry with an easy to use, working alternative to IDM & MVD that can be readily developed and re-used.

6.3 The need for a common method of defining BIM deliverables

One of the principle difficulties in realising efficiency gains through the use of BIM is a function of defective communication stemming from, amongst other things, a general lack of standard terminology and methods of describing process and deliverables.

In the absence of existing simple standard methods of defining the content of BIM information exchanges the BIM-Info Delivery Protocol attempts to fill this gap. Furthermore, beyond aligning information needs and creating greater certainty through intelligent and value-adding deliverables, the final built product will have an increased propensity to be as expected.

6.4 Summary of the key features of IDS

The BIM-Info Delivery Specification seeks to provide a simple standard method of describing information exchange content. As a decision-support tool, its key elements can be readily identified per the illustration below.



Figure 11: BIM-Info Delivery Specification – Constituent Parts

Through the use of these generally understood and commonly recognised concepts, brought together in a standard way, the IDS can help enable succinct communication of content requirements for key information exchanges. At the core of this process is defining, BIM-Use, Information Exchange (No. within the series), Delivery Date, Responsible Party, Level of Detail, Receiving Party, and Delivery Format.

7.0 Further Research

It may prove possible to generate machine-readable model information content definitions through the XML schema making it possible to standardise such contents and deliver project information through automated processes.

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Paper #3:

**Contractual Hindrances to
BIM Collaboration**

**A draft manuscript, awaiting
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Sweden

Authors: Hooper, M. and Ekholm, A.

Contractual Hindrances to BIM Collaboration

Draft Manuscript



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Keywords: BIM, Building Information Modelling, Collaboration, Forms of Contract.

Abstract

Background

Today, Building Information Modelling (BIM) represents a synthesis of challenges and opportunities. Here in Sweden, one of the challenges is enabling a suitable platform for construction project collaboration through design and contracting phases. The use of Integrated Project Delivery (IPD) elsewhere provides some cues as to how this might be achieved.

Problem

BIM promises exponential improvements in construction quality and efficiency but current contractual models do not encourage its use, indeed actively inhibit the collaboration at its core. In Sweden, to help bring BIM mainstream, we need to re-craft existing contractual relationships to facilitate collaborative decision making and to equitably allocate responsibility among all construction participants.¹ Changes are required at national and project level, including commitment among project team members to collaboration.²

Purpose & Aims

This study aims to firstly identify and categorise known hindrances to BIM collaboration in connection with current common contract arrangements, secondly establish key prerequisite necessary for useful collaboration for specific BIM uses, and finally, suggest how the above, together with some of the successful aspects of IPD might be integrated into Swedish design and construction practice.

Scope & Limitations

The study looks at AB 04, ABT 06 together with ABK09 and seeks to identify the key characteristic within these typical contract forms in Sweden which hinder early BIM collaboration. It pulls together the views of a number of industry representatives including architects, engineers, contractors and considers the impact of key elements of IPD on Swedish working practices.

Method & Implementation

The methodologies used to implement this local study include focus group interviews (FGIs) with representatives from diverse AEC disciplines, reference to various case construction projects, and a critical review of the most commonly used contract forms available to construction project participants in Sweden.

Results & Implications

It is anticipated that this study may help the Swedish AEC sector build a case for a move towards IPD where collaboration is at the core of construction enterprise. A first step may be to establish appended clauses to

¹ Ashcraft, H. (2007) Building Information Modeling: A Framework for Collaboration, Published in Construction Lawyer, Vol. 28, No. 3, Summer 2008 © 2008 by the American Bar Association.

² Pfitzner, M., Benning, P., Tulke, J., Outter, N., Nummelin, O., Fies, B. (2010) InPro – D29 – Barriers and Opportunities – Future ICT and Organisational Requirements, The InPro Consortium.

facilitate early collaboration, together with relationship re-structuring to oil the wheels of collaboration and alliance enabling teams at a strategic level to work together towards common goals leading to project success.

Keywords: BIM, Building Information Modelling, Collaboration, Appointment documents, Contracts.

On collaboration:



"Coming together is a beginning. Keeping together is progress. Working together is success." (Henry Ford)³

³ Henry Ford - American industrialist and pioneer of the assembly-line production method (1863-1947)

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1.0 Introduction

1.1 Background

Today DCO⁴ organisations are starting to leverage the benefits of implementing BIM on construction projects; however, to move beyond organisational optimisation, one of the challenges facing sector players is to overcome contractual hindrances to BIM collaboration.

BIM implies new workflows where sharing of data-rich models is part-in-parcel of the design development process and downstream users of digital information, authored by design consultants, can be made use of with confidence and assurance. Today only paper drawings have any contractual status; second and third party participants use digital information at their own risk.⁵

Participants, particularly design consultants must be equipped with adequate contractual provisions for sharing, exchanging and using digital information, not only in order to avoid disputes (which are in any case rare) but to enable and support BIM collaboration processes and certainty beyond organisational boundaries.

*Tighter working together is the key to the future of BIM*⁶ but today existing standard contract forms present something of a hinder to collaboration in connection with the use of digital information. A more integrated approach to project delivery may offer a remedy.

Integrated Project Delivery (IPD), an emerging form of collaborative construction project delivery established through the support of the AIA⁷, represents a new alternative to traditional project delivery. It seeks, amongst other things, to remove barriers to better business by allying and streamlining project team relationships.

The key drivers towards a more integrated form of project delivery stem from a number of deep embedded inadequacies; including cost overruns, and generally poor control over project outcomes.

Whilst Sweden benefits from a relatively non-adversarial construction industry, issues regarding responsibility, liability and intellectual property surface increasingly frequently and if not handed satisfactorily at the outset, can leave project participants exposed to greater risk.

Existing standard contract forms in Sweden are few and today there is increasing pressure on industry to forge new collaborative working partnerships and alliances in order for organisations and the sector as a whole to mature from little-BIM to big-BIM.

1.2 Problem Statement & Research Questions

Further to the author's previous scientific articles dealing with implementing project specific BIM-Plans and defining information deliveries for BIM-Uses, a logical next step is to now look at what are the difficulties in executing such BIM decision support mechanisms in practice. Discussions with industry representatives, issues presented at industry seminars and within industry journals⁸ all indicate that the nature of construction contracts themselves present a significant hinder both to the life-cycle use of BIM as information management platform and the collaboration at the core of BIM.

⁴ Design – Construct – Operate. There is no widely used term-definition which is equally representative of all planning-to-demolition activities with the construction industry. The DCO acronym is adopted here as it builds upon the three major project lifecycle phases. (after Succar, B. 2009)

⁵ Edgar, J-O. (2008) ByggIndustrin – Issue 34 – *Entreprenörer bygger på egen risk* – Nov 2011.

⁶ Bengtsson, P. – WSP, extracted from www.OpenBIM.se 31 March 2011

⁷ American Institute of Architects

⁸ OpenBIM Seminars, BuildingSMART Seminars, Byggindustrin Magazine, Linked-In Discussion Forums, Ten Truths about BIM

Finith Jernigan, AIA suggests that the number one hindrance to BIM implementation is “*Not understanding the difference between cooperation and collaboration, while focusing on the wrong social and organizational structures.*”⁹

Whilst the author’s previous papers attempt to deal with information management questions such as what to deliver when, to whom, thereby aligning BIM deliverables expectations, this paper turns to look at implementation difficulties beyond office boundaries. The questions this study therefore aims to address include:

- ✦ What is it that hinders BIM collaboration in Sweden?
- ✦ How have other countries attempted to address similar hindrances?
- ✦ What are the key BIM-Support clauses or tools necessary to reduce or remove collaboration hindrances? – Are they applicable in Sweden?
- ✦ IPD presents a new business model that both enables and supports the collaboration at the core of BIM – is there scope for similar models in the Swedish context?

These are the questions this study aims to tackle, they are at the forefront of the industry’s concern, and may help to enhance the use of BIM in Sweden from *internally-optimised organisational BIM* to *cross-discipline, project-specific BIM*.

1.3 Purpose & Objectives

Collaboration is at the core of the use of BIM technology across sector disciplines and through facility life cycles. This study attempts to identify and address a number of contractual hindrances to meaningful collaboration in connection with the deployment of BIM in Sweden and furthermore suggest the necessary components to help overcome collaboration difficulties.

Through a review of existing documents, industry interviews, and an investigation of how collaboration difficulties have been overcome elsewhere in connection with the use of BIM technology, this study aims to articulate possible suitable measures to improve project outcomes by means of organisational shifts (to optimise scope of key player buy-in) and strategic BIM-Decision support instruments.

If validated through trial, standard BIM collaboration support mechanisms could be implemented as branch standard through appended contract clauses.

1.4 Focus and Delimitations

The context is limited to the Swedish construction industry and focuses on local deficiencies and peculiarities. The data collected has been largely limited to interviews with a few large, national organisations but does cover a broad and representative range of disciplines.

The context of contractual hindrances focuses on those:

- ✦ In connection with the design – construct – operate process;
- ✦ In connection with planned BIM-Uses
- ✦ In connection with generating a common strategic BIM-Plan: Identifying BIM-Goals & BIM-Uses, Developing Information Exchanges.

⁹ Jernigan, F. (2011) *Not every firm is ready for BIM*, <http://www.shoegnome.com> extracted 13 Oct 2011

1.5 Theory

Whilst technology has enabled a whole new level of collaboration through the use of proprietary BIM tools, the industry has some catching-up to do in terms of contracts, liabilities and risk management. To take advantage of new BIM technologies beyond the boundaries of one's own organisation, changes in project organisation, workflow practices are inevitable:

'Everything has to be done in a more collaborative and structured way, and that's where the real challenges lie'.¹⁰

'A true and functioning BIM-Workflow demands new forms of collaboration and responsibility'.¹¹

Around the world new contract forms that are being developed today are driven by a desire for greater clarity, increased confidence between parties, better conditions for cooperation and shared responsibility. In Sweden, a number of major contractors are developing various forms of transparent construction contract with clients - partnering solutions – which demonstrate a desire for greater collaboration and can be seen to represent a move toward IPD.

There are only a handful of standard contract forms to be found in Sweden today, namely:

- ✦ ABK 09
- ✦ AB 04
- ✦ ABT 06

Built on traditional relationships these agreements shape the basis for the majority of construction enterprises. This small number of contracts and associated process arrangements poses in itself a potential hinder in connection with the deployment and implementation of new BIM working practices, processes and workflows.

Today typically numerous attachments and 'other documents' are appended to the underlying contract making it at best difficult to comprehend hierarchy and which clauses are valid and in any case fail to address matters of consequence in connection with the use of BIM technology.

1.6 Hypothesis

Two hypotheses can be derived from the underlying theory of this study as follows:

Hypothesis #1: It is essential for the Swedish construction industry to overcome a number of key underlying contractual hindrances to BIM collaboration if the sector is to advance from organisational optimisation of BIM implementation towards optimised delivery of projects through the adoption of integrated principles.

Hypothesis #2: The existing standard contractual forms inadequately support BIM collaboration and contribute to the fragmentation of the construction industry (which is responsible for, amongst other things, inefficiency and low productivity). Elsewhere the introduction of IPD and associated supporting legal framework has demonstrated significant improvement in project outcomes. Perhaps similar contractual interventions with supporting mechanisms and protocols have a place in the Swedish DCO sector.

¹⁰ Benedict Wallbank, (2011) RIBA Journal: July / August 2011, RIBA, London.

¹¹ Argéus, J., Hasselberg, P. (2011) *BIM för Analysis och Dimensionering*, Examensarbete, Department of Structural Mechanics, Lund University, Lund. Original form: 'Ett äkta BIM-arbetsflöde kräver därför helt nya samarbets- och ansvarsformer'.

2.0 Literature Review

2.1 Key Documents

As part of a literature review in connection with this study a number of key documents were collected and reviewed. These key documents can be identified and appraised under the following headings:

Existing Agreement Documents:

- ✦ ABK 09 (Consultants form of appointment)
- ✦ AB 04 & the Generalentreprenad form (Traditional form of contract)
- ✦ ABT 06 & the Totalentreprenad form (Design and Build form of contract)
- ✦ Avtal för digitala leveranser 2010 (Agreement on digital deliveries)

External Documents:

- ✦ AIA Document E202-2008 & Integrated Project Delivery (IPD)
- ✦ BIM PEPG (The buildingSMART alliance™ BIM Project Execution Planning Guide)

2.2 ABK 09 (Allmänna bestämmelser för konsultuppdrag inom arkitekt- och ingenjörsvksamhet)

ABK 09 is the standards form of contract for the appointment of Architectural and Engineering Consultants in Sweden. It is neutrally written with regards to the details of how Consultants exchange and deliver design information for construction. Often separate project specific appendixes are added to this form of agreement to deal with matters of information management.

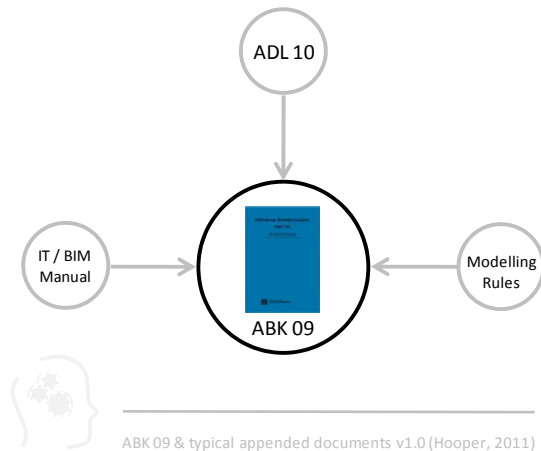


Figure 1: ABK 09 & typical appended documents

ABK 09 regulates:

1. The parties' relationship
2. Scope of works
3. Organisation
4. Implementation
5. Timing of key events
6. Responsibilities

7. Access rights and property rights (for example for future exploitation of results and experiences from the commission)
8. Right to the invention (Intellectual Property Rights)
9. Allowances
10. Payment
11. Termination of commission
12. Insurance
13. Dispute resolution

For the purpose of standardising conditions for consultancy contracts ABK 09 has been developed from previous versions in an attempt to meet today's requirements. However the form makes no reference or accommodation for provisions to support collaboration in connection with the use of digital information and BIM.

Amongst other things, this standard form of agreement regulates copyright and responsibility for design information presented as paper drawings and as such, is not tailored for digital information or BIM.¹² However there have been efforts to bridge this gap with appended documents such as the *Avtal för digitala leveranser 2010* (ADL 10).

Deficiencies in a BIM world

ABK 09 lacks any form of specific support for integration. It has no provisions for either strategic collaboration or projects centred around BIM technology and processes and is in a recent investigation summed up succinctly with the statement below:

“There is nothing in ABK09 that regulates who owns the digital information, what the copyright is worth and what access rights are valid, or even responsibility for the accuracy and correctness of the digital information.”¹³

These deficiencies have attempted to be addressed through the option to append the standard form *Avtal för digitala leveranser 2010* (ADL 10).

2.3 AB 04 & the Generalentreprenad form (Traditional)

AB 04 (Allmänna bestämmelser för totalentreprenader avseende byggnads-, anläggnings- och installationsarbeten)

Designed to support a traditional procurement (*Generalentreprenad*) method AB 04, approaching 8 years old, offers little support to BIM concepts and the implied early project team collaboration.

The AB family of contract forms are set out with similar chapters covering responsibility, fees, etc.

What is not regulated in AB is:

- ✦ Collaboration Methods
- ✦ Compensation and strategic incentives
- ✦ How sub-contractors are procured and managed

¹² Edgar, J-O. (2008) Byggindustrin – Issue 34 – *Entreprenörer bygger på egen risk* – Nov 2011

¹³ Håkon Blom, HL Blom Konsult AB

The design and construction process associated with AB 04 *Generalentreprenad* Contract Form compromises opportunity for cross discipline collaboration centred around the BIM and makes a clean cut between the design phases and construction phase.

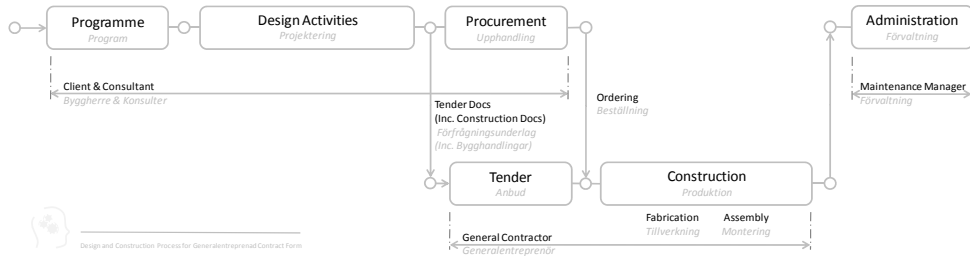


Figure 2: Design and Construction Process for *Generalentreprenad* Contract Form

Generalentreprenad Form

The Swedish *Generalentreprenad*, or general procurement system, shares some of its main characteristics with the British traditional method (save, the role of the architect). The client typically initially appoints a Project Manager as representative who advises the client on further appointments. Contractors tender on the work based on completed design documentation and the client’s only contractual relationship with the contractors is that with the main or general contractor (*Generalentreprenad*). The main contractor procures subcontractors to carry out work sections but is responsible for coordination of the build and the performance of subcontractors.¹⁴ Subcontractors may have design portions, but are often on board after the main design effort is complete.

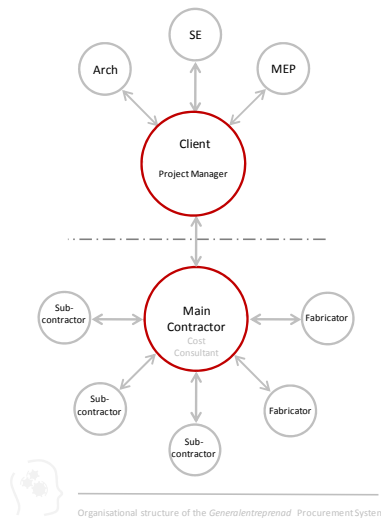


Figure 3: Organisational Structure of the *Generalentreprenad* Procurement System

¹⁴ Noevius, P. (1997) *The Construction Process in the United Kingdom and Sweden*, Lund, Department of Construction Management, Lund University.

As can be observed from the organisational diagram above, the inherent separation of the client and consultants on one side and contractor team on the other, immediately creates barriers, contrary to ideas of team-building, collaboration, and working together towards common goals for the good of the project.

Significant characteristics in the context of BIM planning, information flow & early collaboration:

- ✦ The immediate appointment of Project Manager provides for an impartial representative ensuring decisions comply with project and client interests.
- ✦ Limited overlap of the design and construction phases, compromising scope for design and construction teams to collaborate on design matters.
- ✦ Separation of design and construction activities can inhibit necessary communication, cooperation and feedback between contractors and consultants.
- ✦ Structural and MEP consultants can be appointed too late to contribute to strategic BIM goals and design optimisation activities.
- ✦ Contractor's knowledge, expertise and experience cannot be tapped during the design stages, creating a great waste.
- ✦ Suitable for small and medium sized projects, clients' team retains control over design and quality.
- ✦ Not a suitable system for large, complicated projects where design and construction integration is necessary.
- ✦ Contractor heavily reliant upon consultants to produce design deliverables that are complete and on time. Risk of claims if delayed or incomplete or not fully coordinated with other disciplines.

2.4 ABT 06 & the Totalentreprenad form (Design and Build)

ABT 06 (Allmänna bestämmelser för totalentreprenader avseende byggnads-, anläggnings- och installationsarbeten).

ABT 06 is intended to be used in so-called turnkey projects, ie. contracts where the contractor undertakes total execution and also undertakes to produce all or a substantial part of the design.

Here the main contractor's presence through a substantial part of the design and construction phases enables a high degree of consistency of purpose and team optimisation to occur. However, *totalentreprenad* contracts can lead to a restriction of competition since only a few contractor organisations have sufficient economic resources to manage the design, meaning only a few can compete for the work.

ABT 06 offers little specific support to BIM or BIM processes, but equally no specific hindrance. Often client or contractor organisations will append or insist on the adoption of in-house IT / BIM Manuals setting out strategic and administrative decisions on a project bases. One hindrance here is that there lack of industry BIM Standards in Sweden.

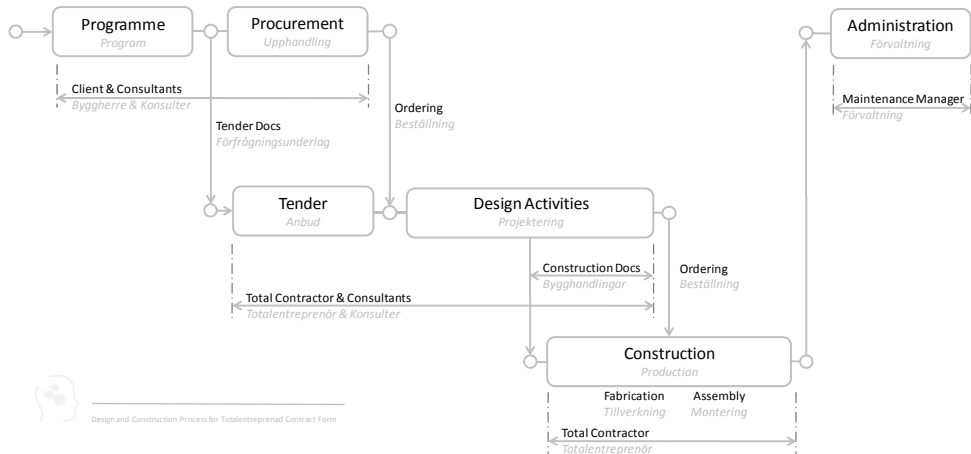


Figure 4: Design and Construction Process for *Totalentreprenad* Contract Form

Totalentreprenad Form

The standard agreement for *Totalentreprenad* is ABT 06 (Allmänna bestämmelser för totalentreprenader avseende byggnads-, anläggnings- och installationsarbeten) described above.

The Swedish *totalentreprenad* form corresponds in principle to the British design and build procurement system whilst "*renodlad*" *totalentreprenad* could be said to match the American turn-key contract in which the client provides only a skeleton brief detailing functional requirements upon which the main contractor develops the building design. Clients may employ an Architect to develop a programme and concept design

who may later be novated¹⁵ to the *Totalentreprenör*. The number of projects under this form of contract in Sweden varies from year to year, but the system has been known to account for more than 50% of the market.¹⁶

This contract procurement system is an example of a response to the increasing need for a more integrated design and construction process. Here it is the main contractor who is responsible for the whole (*total*) process of leading and coordinating the integrated design and construction phases and is characterised by the main contractor taking total control over the building project.

The contractor has a single contract covering both planning and execution of the building project and is responsible for constructing in accordance with the current standards and with the functional requirements laid out by the client.

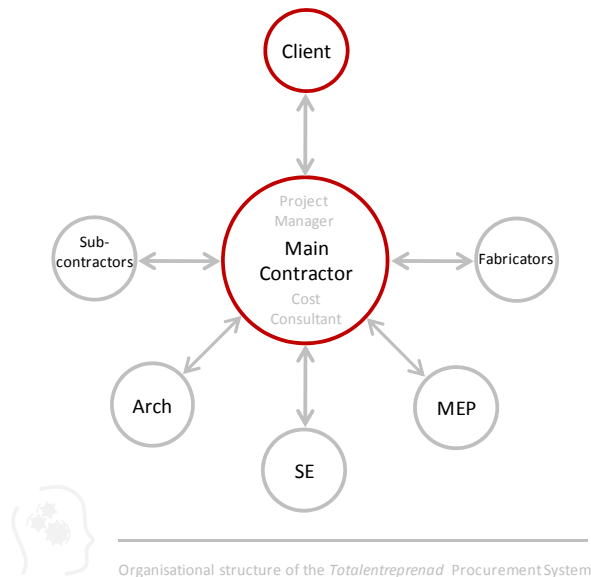


Figure 5: Organisational Structure of the *Totalentreprenad* Procurement System

A project manager is usually appointed to keep a record of client actions and monitor project progress.

Significant characteristics in the context of BIM planning, information flow & early collaboration:

- ✦ *Totalentreprenad* offers the greatest potential for meaningful collaboration since a fuller team is assembled from the beginning.
- ✦ *Totalentreprenad* provides a suitable platform for partnering agreements – a move toward IPD.
- ✦ The total contractor has the opportunity to demand project team compliance with project goals as opposed only internal organisational goals.
- ✦ Client has single point of responsibility. Less control over detailed aspects of the design.¹⁷
- ✦ Contractor is responsible for design and for carrying out the work.

¹⁵ Novation – where a consultants appointment is passed, for example, from client to contractor.

¹⁶ Noevius, P. (1997) *The Construction Process in the United Kingdom and Sweden*, Lund, Department of Construction Management, Lund University.

¹⁷ Cox, S., Clamp, H. (1999) *Which Contract?*, RIBA Publications; London.

- ✦ Construction work can be started earlier as design work can proceed in parallel, however, time required to prepare work packages depends on the complexity of the project.
- ✦ *Totalentreprenad* can be cheaper since the project can be let on a contractor-lead pre-construction plan instead of a completed consultant design.
- ✦ Statutory Consent is a concern since building permits are often not applied for until the contractor is appointed and can take an uncertain amount of time to be granted¹⁸. Delays in this respect can have serious consequences.
- ✦ To be successful, tender documentation must be explicit regarding requirements and expected operation and maintenance costs.
- ✦ Such contracts can lead to a restriction of competition since only a few contractor organisations have sufficient economic resources to manage the design, meaning only a few can compete for the work.

2.5 Avtal för digitala leveranser 2010

Supported and available through OpenBIM, the *Avtal för Digitala Leveranser*¹⁹ is intended to address the contractual deficiencies of ABK 09 with regards to the use of digital information. It contains formal clauses to facilitate agreement concerning delivery and use of digital information for building construction projects (a similar form is expected to emerge for infrastructure projects).

The form can be used to regulate and agree the details regarding delivery of digital information, specifically agreement on:

- ✦ The rights to the output from the commission.
- ✦ Delivery specification of digital information.
- ✦ Control of receipt of that digital information.
- ✦ The clients use and access right to the digital information.
- ✦ The suppliers / consultants responsibility for the digital information.
- ✦ Archiving of design material.

The motivations behind such an appended form are clear, however a number of opportunities have been missed. Examples of parts that need to be further investigated include:

- ✦ The scope of the model including which systems and disciplines to be included for which uses.
- ✦ The level of detail in models for different stages.
- ✦ The accuracy and status (eg scanned, from measured survey, aerial photography, projected etc) of BIM content.
- ✦ Whether the model shall constitute the contract documents or should the extracted 'dumb 2D drawings' be the only valid document.
- ✦ Review and approval processes of design proposals / digital information content.
- ✦ If the model contains too much information how one must sort out what applies for the purpose.
- ✦ Ownership, copyright, etc. need to be reviewed in relation to AB and ABK.

¹⁸ <http://www.byggledarna.se/entreprenadform.htm>

¹⁹ Blom, H. (2010) *Avtal för Digitala Leveranser*, OpenBIM, Stockholm.

2.6 AIA Document E202-2008 & Integrated Project Delivery

AIA Document E202-2008 (Building Information Modeling Protocol Exhibit)

The AIA Document E202-2008 Building Information Modeling Protocol Exhibit²⁰ has been developed specifically to support BIM collaboration and enable project organisations to leverage the benefits of BIM in a systematic way. It presents a formal means of agreeing BIM project priorities and deliverables in a standardised form, enabling teams to proceed with foresight, setting out what models are to be produced and how the models can be used.

The document includes provisions to agree:

- ✦ BIM Delivery Schedule
- ✦ BIM Uses Schedule
- ✦ Level of detail at project stages
- ✦ Model Authorship
- ✦ Model Use Authorisation

The E202 establishes protocols on expected level of detail (LOD) and authorised uses of the BIM data on a project basis. It assigns specific responsibility for the development of each model element to a defined LOD at each project stage.

By contrast, in Sweden there is a lack of standard documentation to enable the expected scope and objectives for BIM to be agreed, detailed and suitably documented. It is conjectured that an adapted version of these 5 concepts may be practical application in Sweden to support cross boundary BIM collaboration.

By formalising these 5 concepts through a standard set of contractual provisions, project participants can nurture a greater clarity of purpose and remove confusion around matters of liability and intellectual property.

Integrated Project Delivery (IPD)

Integrated project delivery is already in use in some form on many projects around the world. It yet has to make its debut in Sweden although it is the source of intense discussion for key stakeholders in the DCO industry. BIM solutions enable IPD and can deliver dramatic advances in technology and process, but the full potential of BIM will not be achieved without adopting structural changes to existing project delivery methods. Key issues regarding compensation, contractual relationships, risk allocation, and so forth can be overcome. Greater awareness, owner mandates, and industry initiatives are critical to the widespread adoption of new delivery methods.²¹

The American Institute of Architects (AIA) defines IPD as:

“a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction.”²²

According to the AIA’s Integrated Project Delivery: A Guide, the defining characteristics of IPD include:

²⁰ AIA (2008) *AIA Document E202-2008: Building Information Modeling Protocol Exhibit*, AIA and AIA California Council, California, USA.

²¹ Autodesk (2008) *Improving Building Industry Results through Integrated Project Delivery and Building Information Modeling*, Autodesk Whitepaper, Autodesk: California.

²² AIA (2007) *Integrated Project Delivery: A Guide, Version 1*, AIA and AIA California Council, California, USA

- ✦ Highly collaborative processes that span building design, construction, and project handover.
- ✦ Leveraging the early contributions of individual expertise.
- ✦ Open information sharing amongst project stakeholders.
- ✦ Team success tied to project success, with shared risk and reward.
- ✦ Value-based decision making.
- ✦ Full utilization of enabling technological capabilities and support.

Teams are galvanised to work together though the use of BIM as a knowledge manager. Here communication is simplified through the means of a knowledge hub (see Figure 6 below).

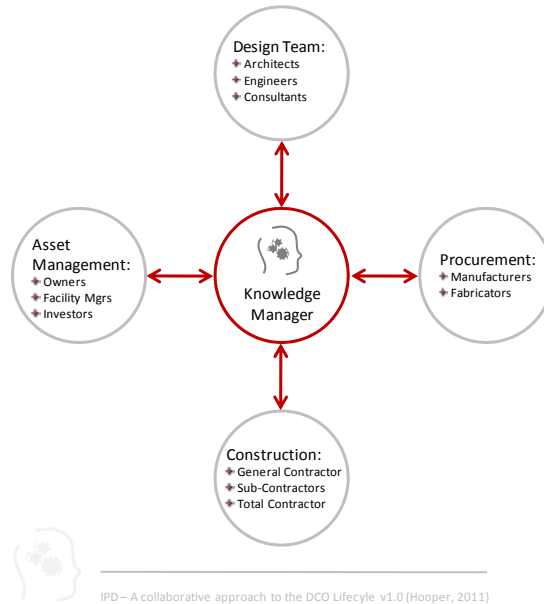


Figure 6: IPD – A collaborative approach to the DCO Lifecycle

'IPD is an incredible expression of what the AEC/FM industry can do when it decides to work together to solve a problem. It succeeds really well at dealing with the whole'.²³

Key Drivers: What are the industry trends that are driving a move towards a more integrated project delivery method? A convergence of forces seems to be moving the AEC industry in the direction of integration based on economics, productivity and the need to extend beyond internal organisational optimisation to project optimisation.

Contracts and Relationships: With IPD the relationships of project participants are fundamentally altered, which gives rise to the demand for new forms of standard contract documents (such as the AIA E202-2008) that address important issues such as compensation, risk allocation, and intellectual property. Already in the industry changes in business models, scopes of services and deliverables are redefining the relationships of interested parties around measured outcomes.

2.7 BIM PEPG (The buildingSMART alliance™ BIM Project Execution Planning Guide)

²³ Cohen, J. (2010), *Integrated Project Delivery: Case Studies*, AIA California Council 2010, Sacramento, USA.

The buildingSMART alliance™ BIM Project Execution Planning Guide (BIM PEPG)²⁴ is a new supporting guide with the primary aim to help construction professionals clarify roles and responsibilities, determine scope and level of detail, cut costs and optimise return of investment (ROI).

The plan claims that to successfully implement BIM, a project team must perform detailed and comprehensive planning. A well documented BIM Project Execution Plan will ensure that all parties are clearly aware of the opportunities and responsibilities associated with the incorporation of BIM into the project workflow. A completed BIM Project Execution Plan should define the appropriate uses for BIM on a project (e.g., design authoring, cost estimating, and design coordination), along with a detailed design and documentation of the process for executing BIM throughout a project's lifecycle. Once the plan is created, the team can follow and monitor their progress against this plan to gain the maximum benefits from BIM implementation.²⁵

The plan suggests that project participants from the earliest stages generate a strategic BIM-Plan that enables agreement on common goals through 4 key steps:

- ✦ Identify high value BIM uses during project planning, design, construction and operational phases.
- ✦ Design the BIM execution process by creating process maps.
- ✦ Define the BIM deliverables in the form of information exchanges.
- ✦ Develop the infrastructure in the form of contracts, communication procedures, technology and quality control to support the implementation.



Figure 7: BIM PEPG – Steps 1-4 (After Anumba et al, 2010)

BIM PEPG provides a useful resource for teams to set out project goals as part of an integrated effort to collaborate meaningfully and deliver a BIM project.

²⁴ Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2009), *Building Information Modelling Project Execution Planning Guide*, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

²⁵ Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2009), *Building Information Modelling Execution Planning Guide*, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

A pilot study²⁶ was recently launched by the author which sought amongst other things to assess the suitability and practicality of implementing such a project-orientated strategic BIM-Plan as part of project procurement in the Swedish construction sector context.

Amongst the key findings, this study identified that although the participants thought it was a good idea to have a strategic BIM-Plan for each project, the following difficulties were revealed:

- ✦ The BIM-Plan required to be implemented at the early design phases meaning owner, design team and contractor buy-in. Many key project participants were not and could not be present – such as the main contractor and key sub-contractors – since they had not been appointed yet and were simply not on the scene.
- ✦ Absence of key players during the implementation of a so-called project-wide BIM Implementation Plan compromised its purpose and diluted its credibility.
- ✦ A tendency for individual consultant disciplines to focus on their own contribution rather than the down-stream use and value of their design effort prevailed.
- ✦ Participants agreed that some sort of common strategic BIM plan was of benefit and helped to address the deficiencies of existing guides.

However a shift in project organisation from *Totalentreprenad* toward IPD indicates it may be possible that the fundamental difficulty associated with the timing of appointments and formation of the core team can be overcome.

It is further conjectured that as part of a move to incorporate collaboration supporting mechanisms and protocols, a project specific, common strategic BIM-Plan is a necessary component to enable delivery of a collaboration-rich project.

3.0 Method of Investigation

3.1 Understanding Contractual Hindrances to BIM Collaboration Using FGI's

The main findings on contractual hindrances to BIM collaboration build on an critical analysis of the key documents mentioned and applies Focus Group Interviews (FGI's) as secondary research method of data collection to identify where the industry perceive hindrances exist and assess the level of concern. FGI's differ from surveys and questionnaires as they not only enable the collection of more in-depth data on contractual hindrances, but they also provide a forum for the different disciplines within the AEC industry to share and clarify their views on various contractual and collaborative issues.

The data gathered is largely qualitative, and has been analysed to discover and highlight the key components that influence the particular phenomena under study and enable a clearer understanding of both the existing contractual hindrances to BIM collaboration in Sweden and what concepts may be relevant to address these hindrances.

As with any research, the reported study has limitations. The following limitations are highlighted in order to frame the context of the research findings:

- ✦ Whilst the FGI method enables the collection of more in-depth information on the topic studied, it also limits the number of participants compared to quantitative methods such as questionnaires.

²⁶ Hooper, M., Ekholm, A., (2010) A Pilot Project - Toward BIM Integration - An Analysis of Design Information Exchange & Coordination, Proceedings of the 27th Annual CIB W78 International Conference - Applications of IT in the AEC Industry, Cairo, Egypt. 15-17 November 2010.

Therefore it is argued that the findings from FGI's are possible to be influenced by the subjective views of the participants.

- ✦ Although the interviewees approached for this research are key players from different AEC disciplines who have been involved in building projects of different scales and with international references, all interviews were conducted in Skåne, Sweden with all participants being based in local branch offices within national organisations. The findings may therefore be influenced by the specific perceptions and culture of practices in the region.

4.0 Data Collected

6 interviews were carried out involving the necessary industry participants including architects, engineers and contractors.

The interviews were semi-structured and focused on discussions centring around the identification (from a user perspective) of known contractual barriers to the use of BIM in connection with the functioning of AB 04, ABT 06, ABK 09, ADL 2010, E202-2008 and in-house IT/BIM manuals. Respondents were asked to suggest where they thought obstacles to collaboration exist, in particular in relation to:

- ✦ Existing contractual provisions.
- ✦ Downstream transmission of digital information (information exchange).
- ✦ The ability to create and implement common, project-specific strategic BIM plans.
- ✦ Successful project coordination with regards to level and commitment to collaboration.

Further specialist consultations were carried out to gain deeper insights into potential for change and measure the desire within the industry to improve collaboration on BIM projects.

4.1 Focus Group Interviews (FGI's)

The interviews with industry consultants focused on collecting responses to the forthcoming key questions and points of view in relation to the diagram below derived from the hypothesis.

The diagram presents the existing contract documents to be found in Sweden today, together with a number of ancillary documents that are emerging within the industry here and elsewhere that are purported to support BIM processes and facilitate enhanced cooperation. Respondents were asked to consider the relevance, application and suitability of all interconnected documents and their influence on project team capacity and propensity to collaborate on BIM projects.



Contract Documents – The necessary parts for BIM-Projects v1.0 (Hooper, 2011)

Figure 8: Contract Documents – The necessary parts for BIM-Projects

4.2 Respondent #1: A Major Multi-Disciplinary Engineering Consultant Organisation

From your experience can you identify (from a user perspective) known and suspected contractual barriers to the use of BIM in connection with the functioning of AB 04 / ABT 06 / ABK 09 / ADL 2010 / E202-2008 / IT manuals.

Agreements ABK, AB and ABT are neutrally written with respect to information management, but in practice it is not uncommon for these to be supplemented by appendixes to the contract which attempt to clarify how information management will take place. One hinder here is that there lacks a standard method or form for setting this out and can require referral to legal experts.

In *Administrativa Föreskrifter (AF)* (Administrative Provisions) one can introduce points relating to the handling of information management. Through these clauses it may be possible to make official reference to the appendixes attached to the contract, however, examples of parts that need to be investigated and developed in connection with the use of BIM include:

- ✦ The scope of the model, the systems and disciplines to be included at any given time.
- ✦ The level of detail in models for different stages.
- ✦ The accuracy (measurement) and status (eg: from scanning, was measured, aerial photography, etc)
- ✦ Whether the model should constitute as contract document or should this remain as the drawings extracted from the model?

- ✦ A standard review and approval process or mechanism needs to be established for use with BIM or digital deliveries.
- ✦ Models often contain too much information for the purpose - one must be clearer about what the models are for and what content is required for its purpose.
- ✦ Ownership, copyright, etc. needs to be reviewed in relation to AB and ABK.

Here one can quickly identify a number of key areas where the existing branch standard agreement documents appear to be deficient. It is apparent that there is real need for better supporting mechanisms for agreeing and documenting decisions relating to the use of BIM which has a direct bearing on scope and extent of meaningful collaboration.

There appears to be a demand for greater consistency in the use of BIM. Internal so-called IT / BIM manuals have a significant bearing on internal operations whilst there appears to be a lack of focus on what is needed to aid and streamline collaboration across the project team.

Suggest where you think obstacles to collaboration exist, in particular in relation to:

- ✦ *Downstream transmission of digital information (information exchange).*
- ✦ *The ability to create and implement common, project-specific strategic BIM plans.*
- ✦ *Successful project coordination.*

A fear exists of data being wrong. It's easier to take responsibility for the information on 2d drawings than a data rich model. The submission of drawings (the use of which can be more easily controlled) as part of the contract is safer, and a more comfortable means of formal information exchange. Because models and the data within them are not considered contract documents, they are essentially shared with a precautionary 'for information only' status.

Whilst BIM-Plans, documenting BIM-Goals and BIM-Uses are usually part of the scope of the project IT-Manual, they rarely involve all parties.

The diagram above (Figure 8) suggests a number of key concepts purported to support an integrated delivery process.

- ✦ *Is there an appetite in Sweden to use some or all of these concepts in practice today?*
- ✦ *Suggest where you think obstacles to exist in adapting these as branch standards in Sweden.*

Not all documents suggested as 'missing' (per Figure 8) are in fact missing. BIM-Plan's for example are often in some form contained within project specific BIM-Manuals.

Contractual hindrances are perhaps not the major issue when considering obstacles to collaboration. Instead, the mindset of the many project participants is not BIM-ready.

There remains a tendency to define carefully and defend one's own organisations' contribution and not to act in a way that is necessarily to the benefit of the project.

Another area that is problematic is defining responsibility for digital information.

The respondents thought it was unnecessary to consider a separate *Object Author Matrix* as consultant's scope of work together with the use of BSAB codes (eg A for Arkitekt, K for Konstruktör) for respective models is often deemed adequate for author identification purposes.

However there are a number of areas where the responsibility (for authoring and maintaining correctness) of digital information remains problematic. Examples of these are:

- ✦ **Holes** – for example in structural elements for services. Here architect, structural engineer, MEP engineer and precast concrete sub-contractor must collaborate to ensure accuracy. Deciding overall responsibility for correctness is difficult but, for the sake of clarity, needs to be defined.
- ✦ **Doors** – this element often requires input from multiple design participants. Client, Architect, Electrical Consultant, Fire Consultant, Security Specialist, Suppliers to name a few, all are likely to have input to the specification of such an item. Here some organisations have set up specialist information management systems connected to design models to manage multiple source inputs together with a specification approval system. However overall responsibility for correctness and coordination often remains undefined and ultimately unclear.
- ✦ **Geotechnical data** – Geotech personnel amongst other things are charged with the task to take borehole samples, for example on a 10m grid, and present the results. Meanwhile it is often the task of the Land Engineer to interpret the results into a meaningful model recording ground conditions. The Land Engineer is expected to guess correctly the existing ground conditions between bore holes and present this information through his model. Here there can be confusion of responsibility for the information and when the ground model is found to be inaccurate (eg rock is discovered unexpectedly), a blame culture proliferates.
- ✦ **Quantities** – who is responsible for quantity take-off? Typically the model(s) is authored by the Architect and Engineering Consultants then passed to the quantity take-off team within the Contractors organisation. To succeed, the BIM needs to be authored correctly, using standard naming of objects and objects must be modelled correctly. Modelling rules within organisations for these purposes are now being developed and tend to be software product-specific. A close collaboration between consulting team and contractor is necessary for automation of this process to be realised. In Sweden, because the role of ‘Quantity Surveyor’ does not separately exist, determination of overall responsibility for the correctness of this critical data remains problematic.

Such matters of responsibility are often resolved during the project design authoring phases on an ad hoc basis. However it is here that improvement can be realised for the betterment of collaboration and for the good of the project. In order for these matters to be resolved expediently, clarity of roles and information responsibility, an established framework for collaboration and perhaps most importantly trust needs to be present to ensure success.

If a precarious and negotiated consensus has to be agreed over and over by unstructured and sub-optimal means, the project team participant are exposed to unnecessary risk.

4.3 Respondent #2: A National Architectural & Project Managing Organisation

From your experience can you identify (from a user perspective) known and suspected contractual barriers to the use of BIM in connection with the functioning of AB 04 / ABT 06 / ABK 09 / ADL 2010 / E202-2008 / IT manuals.

There is a feeling in the industry that risk and reward is not amicably distributed amongst project team members. In hard economic times it is difficult for consultants to raise their fees or sell new or additional services that leverage the value of the digital information they author. In this respect the ideas behind IPD with regards project economy are of interest to consultants who, to some extent, feel are getting a rough deal for their effort.

In connection with the use of BIM in general, the diagram below suggests that those who benefit from the BIM process and technology are not necessarily those who are the leaders investing in BIM infrastructure.

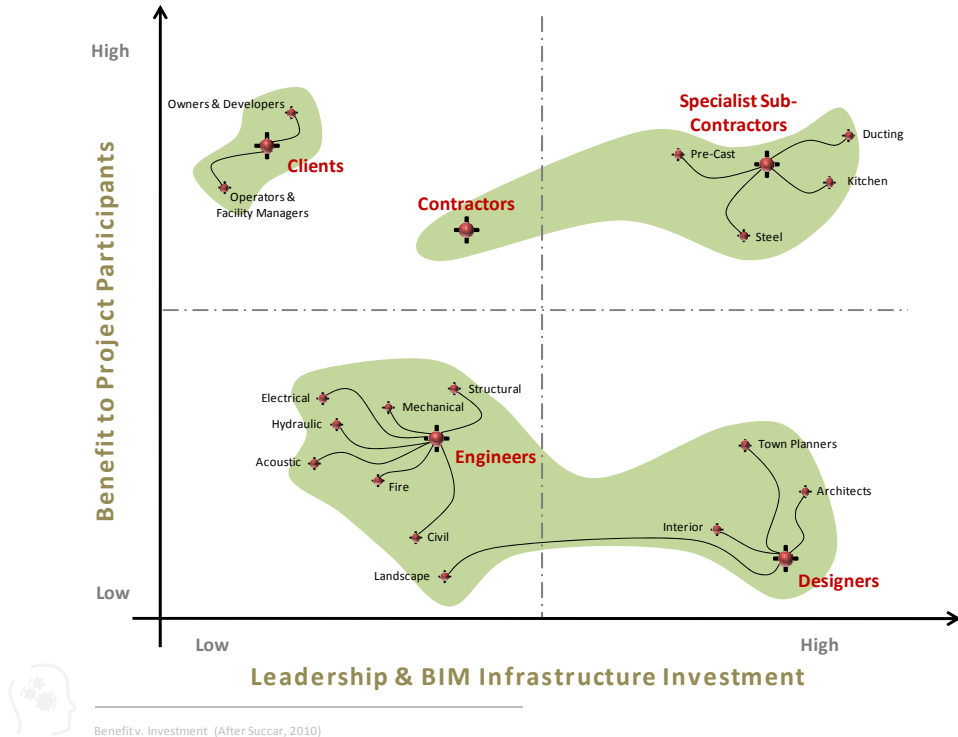


Figure 9: Benefit v. Investment

Agreement was expressed regarding difficulties in defining responsibility for correctness of information particularly where cross-discipline input is required. Examples of these, as mentioned include doors and voids or holes for services through walls and floors.

Doors have been of particular interest for this respondent who, with technical support, has created a series of proprietary tools to help manage technical input from multiple sources together with an approval or sign-off process. The need for these kinds of information control systems is testimony to the need for better information management and clarity of responsibility.

Suggest where you think obstacles to collaboration exist, in particular in relation to:

- ✦ *Downstream transmission of digital information (information exchange).*
- ✦ *The ability to create and implement common, project-specific strategic BIM plans.*
- ✦ *Successful project coordination.*

Many of the larger, more developed sector players have their own in-house IT/BIM manual which of course is a good thing, but there is no common standard for their contents or connection to the quality of their product. It could even be said that the in-house IT/BIM manual contributes to fragmentation of approaches. What is needed is branch standards and greater teamwork.

BH90²⁷ the industry's digital information handbook presents something of a hinder generally as it's too abstract and lacks concrete examples for users.

The diagram above (Figure 8) suggests a number of key concepts purported to support an integrated delivery process.

- ✦ *Is there an appetite in Sweden to use some or all of these concepts in practice today?*
- ✦ *Suggest where you think obstacles to exist in adapting these as branch standards in Sweden.*

Documenting anticipated level of development against each project stage would be useful – particularly when it comes to 3d coordination which is best done when all contributors reach the same level of detail at the same time.

Responsibility for information is to some extent dealt with within a discipline division lists, however, as mentioned, difficulties arise where multiple input is required. An Object Author Matrix could be useful to help regulate this in conjunction with the BSAB coding for A / K / EL & VVS disciplines.

4.4 Respondent #3: An Architectural Organisation

From your experience can you identify (from a user perspective) known and suspected contractual barriers to the use of BIM in connection with the functioning of AB 04 / ABT 06 / ABK 09 / ADL 2010 / E202-2008 / IT manuals.

ABK doesn't present any specifically hindrance but in itself offers no direct support to BIM workflows or collaboration routines either. Often a number of attached documents help clarify matters. ADL 2010 is still relatively new and has not been used so much yet. IT/BIM-Manuals often are important documents that are intended to drive forward standards and quality control within an organisation. They attempt to overcome certain barriers, however often lack a common approach.

Suggest where you think obstacles to collaboration exist, in particular in relation to:

- ✦ *Downstream transmission of digital information (information exchange).*
- ✦ *The ability to create and implement common, project-specific strategic BIM plans.*
- ✦ *Successful project coordination.*

We have our own CAD manual based on Revit but lack a set of modelling rules for specific BIM uses – this would be useful for internal use and help us author models of suitable quality for use by downstream users. However, at the moment we only issue models 'for information 'only' and issue a set of drawings as contractual documents.

Control over how downstream users are authorised to use the information was thought unnecessary, however the matter of copyright and intellectual property rights is a concern. Often we are forced by client or contractor to waive the copyright over the designs we produce.

A form of BIM-Plan is included in our CAD manual which helps deal with a number of strategic matters. Part of our CAD manual is developed to be project specific and aims to deal with our internal goals agreed with our clients.

²⁷ SI, Swedish Standards Institute (2008), *Bygghandlingar 90 : byggsektorns rekommendationer för redovisning av byggprojekt*. D. 8, Digitala leveranser för bygg och förvaltning, Stockholm : SIS Förlag AB.

The diagram above (Figure 8) suggests a number of key concepts purported to support an integrated delivery process.

- ✦ *Is there an appetite in Sweden to use some or all of these concepts in practice today?*
- ✦ *Suggest where you think obstacles to exist in adapting these as branch standards in Sweden.*

Often timescales for deliverables are connected to major project stages which are set out approximately in the contract. Exact timings are decided amongst the project team members. A BIM Delivery Schedule may be something useful in the future.

With regards methodology & standards, the feeling is that Denmark has come much further with their bips guidelines. In Sweden there is less attempt by the state to steer process and outcomes in the construction industry.

4.5 Respondent #4: A Major Multi-Disciplinary Engineering Consultant Organisation

From your experience can you identify (from a user perspective) known and suspected contractual barriers to the use of BIM in connection with the functioning of AB 04 / ABT 06 / ABK 09 / ADL 2010 / E202-2008 / IT manuals.

Whilst the 'big 3' contractual documents might not represent or facilitate particularly strong hinders to BIM collaboration, they are equally not specifically designed to support either BIM processes or early collaboration. AB 04 is the most problematic with regards to project outcomes as contractor claims are more frequent.

By the same token they collectively fail to adequately support BIM planning, decision making and early collaboration that is critical on BIM projects.

AB 04, ABT 06 and ABK 09 are neutrally written with regards to information management, it is the appended non-standard documents, that attempt to organise and regulate (on a voluntary basis) matters of consequence relating to the use of the BIM.

The Public Procurement Act, *Lagen om offentlig upphandling* (LOU) represents one of the most significant hindrances to BIM collaboration in that it compartments budgetary sums for the procurement of construction projects. Whilst this practice ensures healthy competition and value for money on public projects, once appointed, LOU thwarts both collaboration and incentive for project participant to do what is best for the project.

Another significant hinder is the resistance to change and the preservation of the traditional mindset in which project participants consciously or otherwise raise barriers around their contribution or design deliverables making it difficult to implement new collaborative procedures.

Trust is an issue. A mindset exists that thinks the worst and hope for the best.

It was generally agreed that whilst some aspects of project strategy should to remain internal, amongst other things, to give companies their competitive edge, it would be of benefit to the industry as a whole if branch standard BIM-Planning user forms were available – at least for publicly financed projects. There are a number of areas where, for the good of the project, teams could and should work closer together towards common goals. Why this is not happening appears to be partly down to trust and management prioritisation of *internal optimisation over project optimisation*.

The Public Procurement Act, *Lagen om offentlig upphandling* (LOU) appears partly culpable for the fragmented procurement of consultant services and indeed severely hinders early collaboration possibilities. Here often separate budgets are established for consultant contributions, project management, construction work etc.

Each participant is commissioned on time-cost basis and thereby compelled to watch closely their allotted budget of time and money so as not to make a loss out of the commission. No incentive for adding value to the project exists, quite the opposite, consultants are under pressure to produce the necessary documentation for the minimum cost. They will have competed for the work and will be keen to limit their involvement beyond what is involved to complete their package of work.

Whilst partitioning construction projects up into pots of money may be seen to be advantageous in terms of competitive tendering for the work and use of public money, it does nothing to support the use of BIM and facilitate an integrated project delivery. In private contracts however, no such organisational barriers exist.

Suggest where you think obstacles to collaboration exist, in particular in relation to:

- ✦ *Downstream transmission of digital information (information exchange).*
- ✦ *The ability to create and implement common, project-specific strategic BIM plans.*
- ✦ *Successful project coordination.*

Our feeling is that the project model should become legal documents instead of just 2d drawings – this demands amendments to AB04 and ABT06. Sweden requires more state input to drive matters of strategic importance regarding BIM into practice. BH90, for example, lacks the objectiveness of Statsbygg’s BIM Manual.²⁸ What is needed is clear objectives of what the team wants to get out of BIM, and not just for themselves, for the project’s sake.

The diagram above (Figure 8) suggests a number of key concepts purported to support an integrated delivery process.

- ✦ *Is there an appetite in Sweden to use some or all of these concepts in practice today?*
- ✦ *Suggest where you think obstacles to exist in adapting these as branch standards in Sweden.*

An Object Author Matrix is central to BIM and is something, in template form, that could be branch standard. In addition, a Level of Detail Schedule would be useful. We have a BIM-Plan of sorts contained within our BIM-manual which is in 2 parts: Client part and internal use part. For competitive reasons, we prefer to keep this document private.

4.6 Respondent #5: A Major Contractor Organisation

From your experience can you identify (from a user perspective) known and suspected contractual barriers to the use of BIM in connection with the functioning of AB 04 / ABT 06 / ABK 09 / ADL 2010 / E202-2008 / IT manuals.

ABT 06 is often favoured amongst contractors for the obvious reason that it facilitates a fuller (total) control of the contractor over the project (the total contractor has the potential to steer the project to enable larger profits). There is little support this contract form offers to the use of BIM other than that ABT facilitates the presents of a fuller team at the early stages.

On major projects total contractors, who in Sweden are frequently one of a handful of capable organisations often provide consultants and other project team members with a set of IT/BIM requirements set out in a IT / BIM Manual. This can include amongst other things:

- ✦ **Modelling Rules**

²⁸ Statsbygg (2009), BIM-Manual 1.2: Statsbygg Building Information Modeling Manual - version 1.2, Oslo: Statsbygg.

✦ A BIM-Delivery Schedule

Suggest where you think obstacles to collaboration exist, in particular in relation to:

- ✦ *Downstream transmission of digital information (information exchange).*
- ✦ *The ability to create and implement common, project-specific strategic BIM plans.*
- ✦ *Successful project coordination.*

BIM-Plans are usually developed in private with the client only. No standard common plan exists.

We often receive digital information from consultants with varying degrees of usability. On occasion we have known to re-model the entire project to enable us to use the information for 4D (cost scheduling) and 5D (timing scheduling) capabilities of BIM. To address this issue we have developed BIM-Manuals which we issue to consultants on BIM projects.

The diagram above (Figure 8) suggests a number of key concepts purported to support an integrated delivery process.

- ✦ *Is there an appetite in Sweden to use some or all of these concepts in practice today?*
- ✦ *Suggest where you think obstacles to exist in adapting these as branch standards in Sweden.*

A number of the suggested concepts are, in some capacity, already in use. Our BIM-Manual, which is appended to contracts, includes sections which cover model ownership, level of detail, BIM-Planning, BIM-Delivery Schedule. However it may be of national interest to have these as branch standards. Obstacles include lack of client interest and lack of state intervention.

4.7 Respondent #6: A Major Contractor Organisation

From your experience can you identify (from a user perspective) known and suspected contractual barriers to the use of BIM in connection with the functioning of AB 04 / ABT 06 / ABK 09 / ADL 2010 / E202-2008 / IT manuals.

The hierarchy of appended documents to be found with AB 04 can present confusion: quantity schedules, for example takes precedence over project description and the drawings – this could be interpreted as a form of hinder.

The AB family of contracts offer little specific support to the use of BIM and the strategic questions which are relevant in BIM-Projects are mostly covered by BIM-Manuals developed by the organisations involved. However, legal matters are simply not properly addressed.

Suggest where you think obstacles to collaboration exist, in particular in relation to:

- ✦ *Downstream transmission of digital information (information exchange).*
- ✦ *The ability to create and implement common, project-specific strategic BIM plans.*
- ✦ *Successful project coordination.*

On BIM projects we implement an in-house strategic BIM Development Plan together with our clients; however we have not used a common BIM-Plan with all project team members.

As part of our BIM-Manual which we issue to consultants we include a requirements specification for the BIM content which describes which objects require to be in 3D and their properties categories. Difficulties can arise

when taking receipt of models from consultants that we later wish to use for 4D (cost scheduling) and 5D (time scheduling). Often time-consuming re-work is required and sometimes it is simpler to start again.

The diagram above (Figure 8) suggests a number of key concepts purported to support an integrated delivery process.

- ✦ *Is there an appetite in Sweden to use some or all of these concepts in practice today?*
- ✦ *Suggest where you think obstacles to exist in adapting these as branch standards in Sweden.*

Although some of the concepts suggested are familiar, many are not implemented in a standard way across the industry. Our organisation has attempted to fill the gaps with our BIM-Manual and requirements specifications, but greater standardisation may benefit the sector.

There is a desire to standardise industry understanding of the concept of level of detail and this should be adapted to better suit BIM users.

4.8 Summing Up

A consensus of opinion revealed itself in a number of areas:

- ✦ Low levels of support for BIM processes within existing contractual forms of agreement.
- ✦ Many administrative and psychological obstacles to collaboration and BIM processes exist which are interlinked.
- ✦ What is hindering is perhaps not what is there but what is missing.
- ✦ There is a lack of standardised BIM supporting documents in general.
- ✦ There is significant scope to standardise a number of key BIM supporting concepts and make them available as branch standards.
- ✦ Individual organisations are developing their own internal BIM-Manuals (with the primary objective to optimise in-house processes) which although are attempting to bridge existing deficiencies in guidelines and protocols, are being developed and implemented in an ad-hoc way contributing to industry fragmentation.

Regarding the proposition presented through Figure 8: Constituent parts for BIM-Projects:

- ✦ *Level of Detail Schedule at each Stage* – was something that all respondents thought would be useful to aid and support collaboration. Currently this is missing and no comprehensive standard method of presenting this information as part of contract documents exists in Sweden.
- ✦ Many questions remain over the responsibility for the correctness of digital information. For this reason amongst others, a standard form of *Object Author Matrix* was considered of value in conjunction with an information approval system.
- ✦ Whilst a number of internal BIM-Plans exist (taking various forms) a standard project specific BIM-Plan with an objective to align to whole-team BIM-Goals was recognised to be of benefit.

The augmented diagram below (Figure 10) summaries the substance of the respondents' reactions to the hypothesis chart. It suggests that a core of interconnected supporting mechanisms are desirable and have potential to become branch standard. These components include:

- ✦ A BIM-Plan (including identification of common project goals, BIM-Uses etc)
- ✦ A BIM Delivery Schedule
- ✦ A BIM Authorised Uses Schedule
- ✦ A Level of Detail at Schedule at each Project Stage
- ✦ An Object Author Matrix

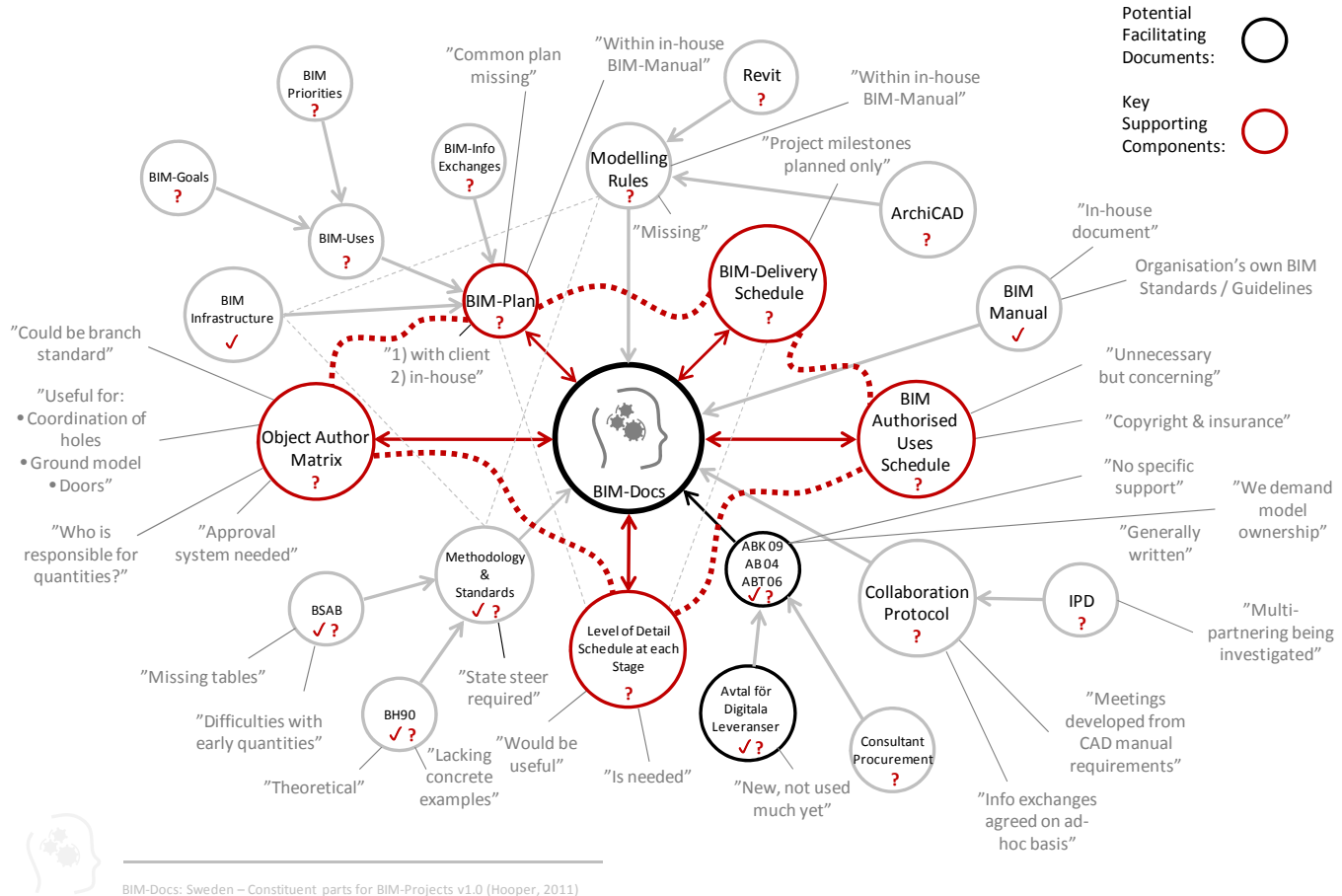


Figure 10: BIM-Docs: Sweden – Constituent parts for BIM-Projects

Scepticism prevailed regarding the relevance of an *Authorised Uses Schedule* (documenting how the recipient of a model may use the data) – since today models are generally only issued *for information only*, and for this reason the author sees no reason to regulate the recipient's use of it. But a model can potentially be used for a raft of different uses (costing, scheduling, performance simulation, code checking, and visualization, to name just a few), it seems obvious that the author of the model should define the suitability of the model for a particular use.

A general consensus emerged agreeing that if these supporting components were lifted from being ad-hoc to being formulated into readily available branch standards, the industry would benefit for a more integrated approach through an enhanced scope for meaningful collaboration.

5.0 Key Issues

The following key issues emerged from the qualitative data collected and here can be elaborated under the following headings:

5.1 Confidence & Standard Solutions

Many sector players are now anxious, and feel vulnerable through all phases of the design – construct – operate process – afraid of being cheated or getting a raw deal. It is this reason, amongst others that clients and contractors prefer to stick to the familiar standard solutions that have principally not change for 15 years or more.

In Sweden, most project participants are unaccustomed to expending extensive time and resource on customised contracts. The industry largely relies on the existing standard contracts and only calls upon lawyers if and when problems arise.²⁹

Contract forms influence the behaviour of the project participants and it can be observed that a tendency exists for participants to edge on the cautious and lean on existing standard contractual solutions which may or may not provide for today's collaboration requirements.

5.2 A Collaborative Culture

Sweden has a positive culture of collaboration, open communication and can be said to be a solution-orientated nation. One only needs to look and Sweden's history to observe its propensity to avoid conflict and strike the middle road.³⁰ Considering Sweden's collaborative culture and cooperative disposition, the potential of the nation to take better advantage of BIM technology is vast; however, optimised levels of cross-sector collaboration have yet to be realised.

5.3 The E202-2008 in its cultural context

There is a stark contrast in business culture between Sweden and the US - where confrontation is rife and lawsuits are commonplace within all sectors. Here, it could be suggested that the US's AIA E202-2008 has been born in response to, or at least in a context of, a culture of litigation and claims that plagues the industry. But it also can be argued that the E202 does more than avert claims, it provides a foundation for early and structured collaboration that is otherwise absent here in Sweden. Notwithstanding the document's roots, it may have a place, insofar as a number of its collaborative supporting principles, in the Swedish construction sector.

²⁹ IPD Workshop, Stockholm, 12 November 2011

³⁰ Hilson, M. (2008) *The Nordic Model - Scandinavia since 1945*, Reaktion Books: London.

5.4 Copyright & other more powerful actors

Often experienced clients demand amendments to ABK 09 particularly in connection with clause 7: The rights to the commission's results. Typically Clients may demand full and unlimited rights to the use of the BIM without compensation to the consultants. Consultants in Sweden appear surprisingly nonchalant to the idea of signing away their work contrasting with the highly protective view British and US Architects exhibit. Intellectual Property Rights, though important to consultants in Sweden, often plays second fiddle to the pressure to release control by more powerful players.

5.5 BIM Manuals

Attributable to the lack or absence of national guidelines, there is a tendency for organisations to develop their own specialised IT / BIM Manuals, often with appendices that are tuned to the requirements of the specific project. These manuals often attempt to address a number of the administrative and strategic matters on BIM-Projects where branch standards and industry literature lack guidance. It can be observed that it is these in-house BIM Manuals that are key to the methodology and implementation of BIM in Sweden and are the industry's response market demand and can be said to represent the industry's desire to press ahead with BIM implementation.

However, the development of multiple, organisation-specific BIM Manuals may over time come to represent a hinder to best practice and hamper potentially for collaboration across the sector. To avert further fragmentation of the construction industry, it can be considered of national interest that BIM approaches, implementation standards and guidelines are harmonised and consolidated, were applicable, into branch standards.

Unlike our Nordic neighbours, the main drivers behind the development and implementation of BIM is being lead by a number of key industry players with resource to invest in R&D in the field (as opposed to national mandate). This is important as it indicates that BIM implementation motivations are more business-orientated, than obligatory.

5.6 Claims Culture

Today *Ändring och tilläggsarbeten* (ÄTA) (Claims for construction variations). Variations, adjustments, alterations, additions or omissions, correctional and additional work, occur in almost all contracts leading to extension of time and extra expenditure. Most contracts usually allow modification works, but the conditions of these can vary greatly. In many cases, the parties establish so-called 'plus-minus-lists' where all ÄTA-work is recorded. A basic rule in most contracts is that the ÄTA-claims must be made before work is performed, or within a certain period of time, otherwise the contractor will lose their right to additional compensation. It should be noted however that the claimant does not always need to price the work accurately. Most often however, the contractor negotiates a price as early as possible, while the client prefers to wait till the end of the contract.

A culture exists, though not as severe as has been in the past, for contractors to make low bids to secure work then make as many claims as possible through the construction phase to claw back money and re-coup on the low bid.

The industry is keen to move away from such negative conspiracies which stifle potential for cooperation and team-working, however, one of the difficulties with today's separatist method of project organisation and remuneration is that there is a risk of falling back to traditional thinking and a claims-culture.

Today, the basic principle regarding remuneration is that the main contractor takes the risk for calculable costs, and the client for non-calculable. Whilst this may make it simpler to define responsibility, it does little to

support an environment of collaboration where achievement of common goals are sought with risk and reward shared.

5.7 Lagen om Offentlig Upphandling (LOU) - The Public Procurement Act

LOU is the law in Sweden that regulates purchases made by public authorities and other organisations who are financed by public money. The law implies compartmentation of money to finance public projects with fixed budgets.

Under LOU-procurement project bids are considered through a series of requirements and criteria, lowest price being one of the highest priorities.

LOU 12 kap § 1 states:

A contracting authority shall accept either:

- ✦ *the bid which is the most economically advantageous for the contracting authority, or*
- ✦ *the bid that contains the lowest price.*

In considering which tender is most economically advantageous, the authority shall take into account various criteria linked to the subject of the contract, such as price, delivery or completion, environmental characteristics, running costs, cost effectiveness, quality, aesthetics, functional and technical characteristics, service and technical support.

The contracting authority shall specify how such criteria will be weighted in assessing which tender is most economically advantageous. Weightings can be expressed as a range with an appropriate maximum spread.³¹

The simplest and most widely recognised criterion is lowest price.

5.8 Risk and Reward

Dialogues relating to the distribution of risk and reward often revert to questions of remuneration and method of measurement. If project teams are to be incentivised to do the best for the project instead of their individual organisation, a longer term perspective is required. Agreements can provide financial incentives that are fair to all participants based on level of risk and effort. Workshop³² participants generally agreed that economic drivers are necessary to justify changes in project team collaboration and process organisation. How this could be applied to the Swedish market warrants further investigation.

5.9 Advanced Planning & Early Collaboration

BIM workflows imply a more intensive work effort during the early stages of construction projects. Early planning to agree matters of strategic consequence such as which the team will be, team building, contract structure, and team objectives can be seen as critical for success.

The early design and planning phases may, as a result of this increase in activity, require to be extended to accommodate the more comprehensive project planning work involved. However, there is a natural resistance to this as traditionally participants prefer to minimise expenditure of resources before the project gets the official go-ahead. In this respect it is important that all parties are aware of the proposed timescales of key decisions and can, in advance, partake in early planning strategies to get the most out of BIM's new working methodologies.

³¹ Goblirsch, G. (2006) Utvärdering av anbud – Powerpoint presentation presenting LOU 12 kap § 1 & 2.

³² IPD Workshop, Stockholm, 12 November 2011

5.10 Articulating Common Goals

Strategic BIM-Plans of one form or another appear to be on the agenda of most the organisations interviewed. Although the content and scope of such plans were not investigated, there may be potential to standardise key elements which relate to establishing project goals. One of the primary goals of the BIM PEPG³³ is to align project team's BIM delivery expectations through, amongst other things articulating and focusing on common goals and developing and common, project-based BIM implementation strategy. Here a standard method of agreeing project goals and deploying the required staff and supporting infrastructure is acknowledge to be a key ingredient to project-long collaboration, however, such plans must be project-wide if to be of value to the project instead of individual organisations.

5.11 Resistance to change

Resistance to change is strong and paradigm shifts in mindset even more difficult to put into practice – particularly where management buy-in is weak or missing. However, optimised use of BIM technologies can be introduced incrementally through deployment of national branch standards, documenting best practice and defining quality standards.

5.12 Dare to Share

There is a genuine fear amongst designers that crucial data may be wrong or out of date. Whilst the delivery of drawings which have legal status doesn't present particular difficulty, the delivery of digital information can require a whole new level thoroughness and quality control which organisations can struggle to put into practice. Organisations and individuals, stuck in traditional thinking, can display a tendency to only share digital information as they would paper drawings: for formal document issue.

Another concern is that design consultants are afraid of giving away too much information (sell short their effort), or of being held responsible for information that, technically, they should not be.

In general, a problem that often arises is that various stakeholders in the project do not *dare to share* their work-in-progress. This can be for various reasons such as:

- ✦ The content has not reached a familiar status level.
- ✦ The content is a varying status level (which has not been or cannot be managed clearly).
- ✦ A fear exists that the receiver of the model may miss-use the data (assume the data is 'frozen or a design final').

Such phenomena contribute to delays in the course of the design process and can be interpreted as hindrances to BIM collaboration.

5.13 BIM-Uses & Data Misuse

With today's complex spectrum of possible uses of digital information it is now increasingly important for both model author and model receiver / user to be clear what the model is for and how it may be used. This has a bearing not just on the legal matter of copyright but on the simple matter of ensuring the right and complete model content is present. Currently there appears to be little evidence of any form of standard method of control of this in Sweden.

³³ Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2009), *Building Information Modelling Execution Planning Guide*, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

5.14 Status of Deliverables / Model Status

The status of various objects within a BIM model is often not so easy to handle, however a mechanism which enables a standard way of describing the model content using at least a broad brush approach of LOD, together with a clear purpose for the model, author and authorised uses (connected to project stages), the picture starts to become clearer.

Here, even if different objects in the same model are at different LOD, the overall model status together with the BIM-Use it is intended to fulfil could be deemed adequate to achieve clarity behind digital deliveries and can be controlled through on-line approval systems accessible to all team-members.

Today, because models and the data within them are not considered contract documents, they are essentially shared with a precautionary 'for information only' status. This both takes the onus off the author for modelling accuracy and creates uncertainty and risk for the recipient.

5.15 Responsibility for correctness & Responsibility for objects that have multi-party input

Tied to the above issue, responsibility for the accuracy of digitally authored building design information remains a muddy issue in Sweden. That's not to say that serious problems occur that can't be solved under the projects management, but without compulsion to author accurately and the existence of a project-wide documented clarity of purpose behind modelling efforts, a short-sighted view of both authoring process and delivery is likely to prevail.

Today discipline models are usually separately defined by use of the initial of the responsible party (eg A for Architect, K for Konstruktör etc). To date this has generally been deemed adequate, however, where multiple models are in use at the same time for various BIM-Uses, and where one author is dependent on another authors contribution, supporting documentation beyond the simple 'A' or 'K' prefix is becoming increasingly important.

5.15 Project Team Interface

Difficulties in information management and delivery generally do not arise within individual organisations but where they interface with other disciplines or where, for example, the consultant team is required to deliver a composite set of information such as a full co-ordinated model. Here, for the avoidance of doubt, contract requirements must be specific regarding deliverables and responsibility for delivery. Standard protocols including key supporting mechanisms may offer the support that's lacking.

The AIA's Document E202-2008 may provide an indication as to how a number of critical concepts might be developed to support collaboration and a more integrated information-sharing process.

When signing up to a BIM project, it could be advantages to all parties if the planned level of information maturity of deliverables, what this means in content and quality terms and who is responsible for authoring, changing and updating the information, were all set out clearly from the start in a standard way.

5.16 Timing & Scope of Appointments

Many of the fore mentioned key issues are phenomena or circumstances that can be rectified or improved through better structured protocols and appropriate addendums to an existing AB contract, however the timing and scope of appointments is a matter which implies significant structural and organisational changes.

With regards to the formulation and implementation of a cross-party BIM-Plan, the timing of appointments has been highlighted as a significant barrier to execution. This can lead discrete organisations to attempt to win what they can from BIM, limiting potential maturity of BIM implementation to organisation level. If BIM is to

mature to sector level implementation through design – construct – operate stages, scope for cross-party collaboration must be present from the outset.

6.0 Findings

6.1 Identification and Categorisation of Factors Hindering Collaboration

In order to appraise factors hindering collaboration, it was thought necessary to permit consideration to a variety of different classifications of hinder in order to firstly, appreciate the interconnectiveness of hindrances generally and secondly, to tease-out those hindrances that may not be immediately obvious. The categories selected to chart known hinders include: contractual, technical, economic and other including those that could be deemed social and / or psychological. The table below records and presents this aspect of the findings.

Factors Hindering BIM Collaboration

Contractual	Technical	Economic	Other (eg social / psychological)
eg Responsibility for correctness of data	eg Interoperability	eg Difficulties in realizing ROI	eg Low client interest in BIM
Common practice to deliver the BIM model as requested, but only take legal responsibility for extracted 2d paper documents.	Consultants must still provide 2d drawings (paper and / or pdf) of design information (in addition to the model)	Big financial investment for consultants both in equipment and training.	Traditional process mindset
ABK 09: BIM model has no contractual status.	This requirement for double information hinders the demand for BIM.	Imbalanced investment v. economic benefit across sector	Resistance to change
Clarity of purpose (BIM-Uses) missing	Still much repetition in data entry due to lack of information stewardship, reliability, chain of information responsibility.	Little scope to realize win-win initiatives	Fragmented industry compartments efficiency initiatives
Lack of branch standard language in connection with BIM-Concepts	Knowledge about each others BIM-Information requirements	Difficulties in distinguishing and defining the boundaries between company BIM business strategy, project based BIM-Strategy and national BIM-Strategy.	
Lack of branch standard method of defining and controlling BIM-Deliveries - ie: BIM-Delivery Schedule	Awareness amongst AEC participants for what information is relevant at what time for what purpose.	Time & money catch 22 - when there is high economy and pressure in the industry there is not the time to spend in developing BIM expertise, when there is a depressed economy there isn't the money to invest in BIM.	
Lack of branch standard method of detailing and controlling responsibility for data - ie: Object/Author Matrix	Awareness for information levels and lack of common expectation of how LOD should develop through DCO phases.		
Lack of branch standard method of developing a strategic BIM-Plan - ie: BIM-Goal, BIM-Uses, BIM-Info Exchanges	Lack of standard method to define status of model content and level of accuracy		
Lack of branch standard method of describing expected level of detail at various project stages	Lack of standard method of reviewing and approving model content.		
ABK 09: Consultants are still required to print out and send 2D paper drawings - it is these that have contractual status			
Lack of branch standard method of detailing authorised uses of BIM data			
ABK 09: Rätt till uppdragsresultatet - consultants often asked to waive rights			



Factors Hindering BIM Collaboration v1.0 (Hooper, 2011)

Table 1: Factors Hindering BIM Collaboration

6.2 A Consensus behind the need for Supporting Mechanisms

A consensus emerged suggesting that the fundamental building blocks of the existing forms of contract found in Sweden are sound and require little change. However some essential investment is needed to develop simple supporting mechanisms to facilitate improved collaboration beyond office boundaries. Branch standard protocols and service schedules to define BIM-specific roles, ways of working and desired outputs are desirable.

Looking forward to achieving an Integrated Project Delivery, there are a number of limited actions related to contract forms, organisation of resources, timing of appointments and remuneration / incentives that could be taken in advance to facilitate early adoption of integrated working.

Greater consistency in relation to the implementation of BIM in Sweden is desirable as the ongoing fragmented, organisational approach presents both opportunity and risk. A significant risk to Sweden – other than the risk associated with a failure to have a national strategic approach to BIM (which the government may chose to address before long) – is the unnecessary and avoidable divergence in strategic direction of BIM to the norm encountered in the Nordics and internationally.

6.3 Summing-Up

Contractual issues have the potential to act as a source of inertia, compromising scope of BIM implementation and hampering cross-discipline collaboration on projects. The development of a limited range of standard BIM collaboration supporting mechanisms, implemented through strategic protocols, can offer clients greater level of certainty over project outcomes and facilitate a more effective collaboration and control of BIM-deliverables that is needed to move toward a more integrated industry.

Given the current level of BIM implementation maturity within the interviewed organisations, the general view is that existing contract forms offer little hindrance to BIM collaboration in themselves, suggesting minimum amendment is required. However, there is a need to agree and document BIM requirements, to a greater and more consistent extent than is being done today, to enhance meaningful collaboration. Moreover, the findings suggest that there is a desire for a number of collaboration supporting mechanisms to be branch standard so that DCO organisations can respond through a consistent framework – rather than through botched appendixes.

Details of BIM requirements today are documented in an ad-hoc fashion according to individual organisation's procedures. *Avtal för Digitala Leveranser*, release in 2010, remains largely untested however already a number of deficiencies are emerging with regards the breadth of its scope and its ability to support collaborative processes.

More than just general BIM requirements should be described and documented if a more integrated process is sought. The use of a comprehensive set of branch standard supportive mechanisms, appendable to existing contracts, may offer the means to reduce or remove a number of collaboration barriers.

7.0 Discussion & Analysis

7.1 Absence of Standard BIM Contract Documents

The lack of existing standard contract documents in Sweden that actively support the use of BIM represents a hinder to collaboration in connection with the authoring of BIM data and indeed the intelligent use of data-rich models throughout the design – construct – operate lifecycle. Without an agreed protocol detailing the working methodologies and standards, it is almost certain that collaborative working will be compromised or fail and others will find the BIM data difficult to use or useless.

This absence of supporting mechanisms could be addressed through the development of a set of comprehensive BIM protocols and schedules specifically designed to support the use of BIM and associated collaborative processes.

Branch standard BIM-Supporting documents may stand to serve the sector in following ways:

- ✦ Validation of branch standard working methodologies by providing a recommended framework for practice.
- ✦ Branch standard documents may provide a platform for establishing a consensus with regards to important emerging matters of consequence such as: risk, responsibility, liability and copyright.
- ✦ Removal of risk associated with ad-hoc BIM-Implementations and diverse approaches.
- ✦ Custom agreements, unless crafted by seasoned experts, often are unbalanced and overlook key issues.
- ✦ Branch standard documents reduce the effort involved in documenting the roles and responsibilities on a project.

There is potential to test, valid and implement a standard set of BIM protocols and schedules through a revised and updated *Avtal för Digitala Leveranser*.

7.2 Sorting out objectives

Clients often specify that *'the team will supply a BIM'* or *'deliver an IFC model'*. This can be perilously vague and has consequences for both parties. The client may be expecting a full collaborative BIM process involving all the design consultants, the contractor developing 4D (programming) and 5D (costings), inputs from sub-contractors and suppliers on their design items and an operational use involving facilities managers. If however, the appointed team thinks the client means a few 3d visualisations on a non-collaborative model then the whole project team is at risk.

It is therefore essential that project priorities and objectives are defined so teams can confirm exactly what is expected. Ideally this should be detailed in writing as part of appointment documents together with a deliverables schedule. Here difficulties arise as there is no standard means of agreeing and documenting this in Sweden.

One of the key duties of consultant organisations is ensuring that properly considered and prepared appointment documentation is in place on a project basis.

Most issues associated with the use of BIM are common sense however, there is not yet any *standard* appointment document for BIM projects. Instead, mutually agreed 'BIM clauses' can be appended to existing standard appointment documentation (such as ABK 09 + Avtal för digitala leveranser 2010 + BIM-Manual).

Teams must defining objectives:

- ✦ Consultants should agree and understand fully what the objectives are for BIM on a project basis. It is essential to ensure teams confirm exactly what is expected – detailing accurately the scope and objectives for BIM on the project and include this as part of the appointment documentation.
- ✦ Schedule of deliverables. BIM workflow implies a greater intensity of input at early stages. It is important that teams don't just recognise this but know what to deliver, when. Projects where 4D and 5D work is expected require considerable input of data from the contractor.
- ✦ Implement BIM Plan detailing the working methodologies and standards. Both PI insurance cover and building contracts rely on establishing and agreeing a protocol.
- ✦ LOD deliverable at each work stage. There is no agreed Swedish document setting this out but the AIA Document E202-2008 describes 5 levels of detail for the BIM model at different project stages, model authorship and scope of BIM information use.

From a practice perspective, Wallbank³⁴ suggests it is essential to have in place the following documents to accompany and support consultant appointment documents on BIM projects:

- ✦ BIM Scope and Objectives Document
- ✦ BIM Delivery Schedule
- ✦ BIM Protocol detailing working methodologies and standards
- ✦ BIM Level of Detail Schedule at each Work Stage
- ✦ BIM Authorised Uses Schedule.

7.3 Who is responsible when consultants work with other consultant's material?

Where for example, consultant engineers receive and develop work originally authored by the architect there is no standard method of defining responsibility for the *original design intent* and the *engineered / developed design solution*.

ABK 09 does not provide any regulator provision for managing this element of collaboration using digital models. On each project the question arises: should we deliver the digital model or just a paper set of drawings? This mindset is rooted in traditional thinking and can be recognised as a significant hindrance both to the downstream use of that digital information and to the overall value of the contribution to the project.

It is still normal practice to extract *dumbed-down* 2d drawings from the BIM for formal document issues because ABK 09 does not recognise digital information deliveries as legal records. This in itself may not be a hindrance as such, in fact it can even be seen positive, however, a consequence is that the downstream users of the information – contractors for example – are forced to use the digital data they receive at their own risk. This scenario rather negates the purpose of building up intelligent models for construction and hinders the teams' propensity to take advantage of data rich models.

One way of addressing this issue maybe to re-consider the contractual status of the model and provide a mechanism for documenting the responsibility and transfer of responsibility of the model through a branch standard protocol.

7.4 Teams must establish early on what information levels should be achieved and when.

Architects may be asked to investigate design alternatives or iterations – they must agree in advance to what level of detail the options should be developed in order to objectively price the work. Figure 11 below attempts to map out possible levels of detail at key DCO stages. Organisations must buy-into idea of agreeing target timescales of achievable levels of detail so that all discipline models have a chance of reaching a level of information maturity that is usable at particular stages.

For example, consultants must communicate level of detail expectations for meaningful 3D coordination at key project stages and be able to deliver. Without a common clarity of purpose behind authoring efforts and alignment of model content and quality, risk for co-ordination fiasco and wasted opportunity remains.

A clear demand has been observed for the industry to improve its contract forms in connection with the use of and collaboration with digital information. The Swedish Building Sector's Development Fund (SBUF) is separately funding a number of focused research efforts – recommendations advocating a standard method of describing level of detail together with applicable uses are on the horizon.

³⁴ Wallbank, B. (2011) *RIBA Journal - Model Procedure*, RIBA Journal - June Issue: London

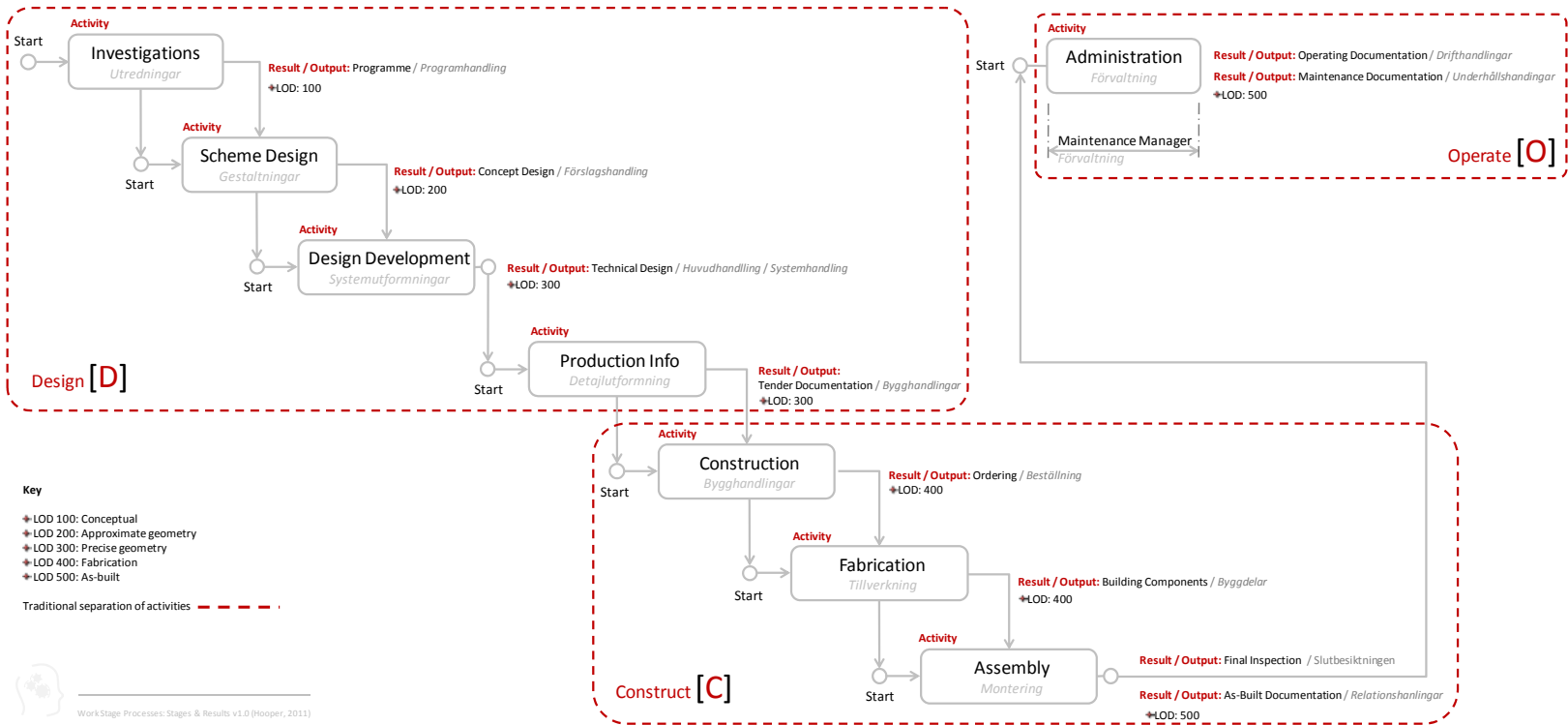


Figure 11: Work stage diagram showing achievable levels of detail

7.5 A Model Procedure

As the benefits of BIM grow increasingly apparent across the sector, the need for supportive contract documentation has become essential. Wallbank³⁵ suggests that it is essential that, as part of a model procedure, one should:

- ✦ Record anticipated level of detail against each work stage.
- ✦ Consider all permissible or envisaged BIM-Uses, for example: 3D design coordination, 4D programming, 5D costings, nD analysis.
- ✦ Consider the BIM-Status at each work stage.
- ✦ Define if and when the BIM becomes a construction document.
- ✦ State if and when the BIM may be used for FM.
- ✦ State that no party is to have liability resulting from the use of the model beyond the uses set out.
- ✦ Record when and to whom a record copy of the BIM model is required (eg at each work stage).
- ✦ Data security: set out where digital information is to be hosted, access rights, and security level.
- ✦ Identify the BIM Manager. This to administrate the implementation of the BIM Protocol: detailing working methodologies and standards.
- ✦ Resist signing away Intellectual Property Rights.
- ✦ Document agreed rights of client and contractor to use the project information.

Whilst some of these recommendations may be misplaced in a Swedish context, they are indicative that there is pressure on the industry world-wide to reconsider contracts and implement BIM-collaboration supporting mechanisms.

7.6 Intellectual Property Rights

Intellectual Property Rights (IPR) and copyright, though is perhaps a less controversial aspect in Sweden, is an important part of consult appointments on BIM projects. Much of the value of the data contained within the BIM lies beyond the building contract, in the management of the built facility through its life. Clients want to use the information in the BIM and expect to have paid the consultants for its use.

In Sweden it is common practice for design authors – Architects and Consultant Engineers – to sign away IPR, under the pressure from more powerful actors. Outside Sweden, however, typically design authors sanction the use of the BIM data in defined and limited ways.

Design authors should be careful not to sell their work short as it is clear the result of a fully collaborative BIM adds exponential value to not just the design and construction process but throughout the lifecycle of the facility.

7.7 Generalentreprenad & Totalentreprenad v. IPD

The *Generalentreprenad* DCO Process illustrated below highlights that there is little contact between design and construction teams through the design process and little involvement of the design consultants through the construction phase. It can thereby readily be deduced that this form of contract and associated process presents little compatibility with any form of integrated project delivery and does little to support BIM collaboration.

There is little scope to implement and coordinate a working BIM-Plan from the outset in conjunction with this form since the very nature of the process and participant relations are fragmented.

³⁵ Wallbank, B. (2011) *RIBA Journal - Model Procedure*, RIBA Journal - June Issue: London

Another important issue is that those individuals with a mindset stuck in this way of working – compartmentation of activities and efforts – also represent a hindrance to both collaboration based on common goals and ultimately project outcomes.

Generalentreprenad DCO Process – Actor Involvement

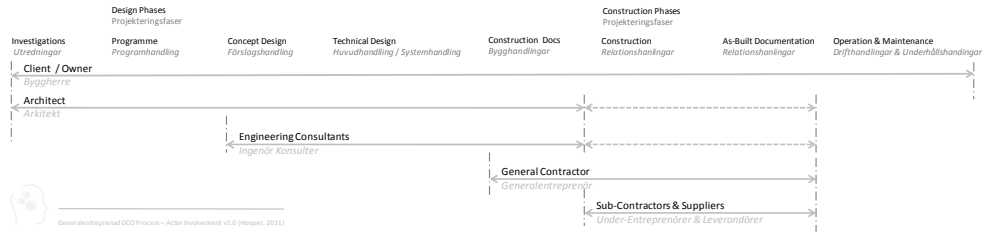


Figure 12: Generalentreprenad DCO Process – Actor Involvement

The *Totalentreprenad* form presents the best potential as a basis to move towards an integrated project. There is significant participant involvement of both design and contracting teams at the early stages meaning that there is scope to deploy a project specific BIM-Plan in which key members can contribute and a team can be formed that can work towards common goals.

Here, since the *Totalentreprenör* has total control over the not just construction, but the design process, it can be held that the practicalities in terms of the organisation of project participants are nearing sufficient for a more integrated delivery – perhaps only a contract form which supports integrated delivery is required.

The *Totalentreprenör* has the scope to pull the team together from the earliest stages when a strategic BIM-Plan can be implemented and the strengths of the team judiciously deployed. (It is well documented that BIM workflows imply increased input from the earliest stages.)

Collaboration hinders identified such as resistance to change to new ways of working, diverse understanding of what BIM is, and lack of process leadership can be addressed under the umbrella leadership of the *Totalentreprenad* form where the *Totalentreprenör* has the opportunity to take ownership of the process. To some extent this is happening in practice amongst the larger contracting firms, but without branch standard terminologies, methodologies and protocols, procedural hindrances still exist.

The diagram below illustrates actor involvement through *Totalentreprenad* DCO process stages.

Totalentreprenad DCO– Actor Involvement

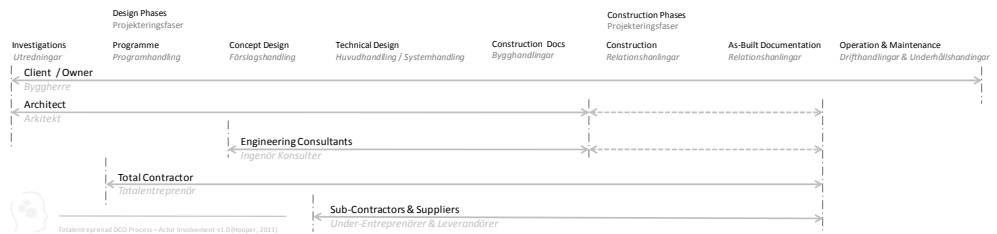


Figure 13: Totalentreprenad DCO Process – Actor Involvement

Whilst the sequence of work stages varies between procurement methods, one thing is apparent: there is clear dislocation of activities and vital communication between the design development phases and the fabrication and construction phases.

Significantly, IPD implies that traditional project phases are adjusted, even refined to accommodate a fully integrated project team and their project participants from the early stages. By involving even specialist sub-contractors and suppliers at the early design phases *construction insight* can be deployed resulting in decisions regarding *what* will be built, *who* is going to built it and *how* it will be built at a strategic and outcome-orientated level. By this means, a more thorough and intelligent building design solution, rigorously analysed and imbued with construction knowledge, results. It is conjectured³⁶ that this results in a shorter construction documentation phase that is re-purposed for the delivery of design information suitable for accelerated construction.

The diagram below illustrates actor involvement through IPD DCO process stages.

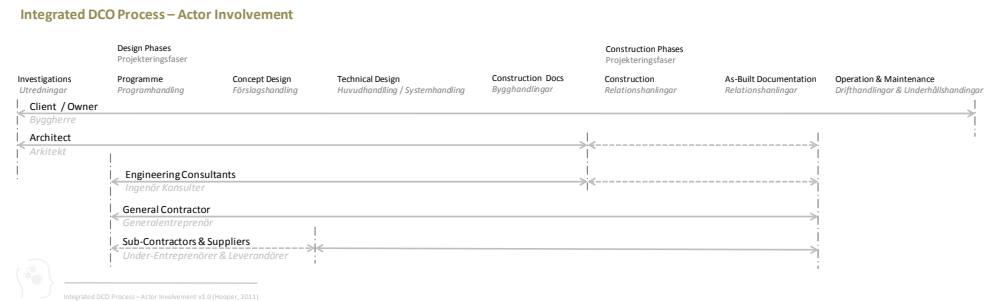


Figure 14: Integrated DCO Process – Actor Involvement

In an IPD form an agreement ties together all the main parties in the project and the supporting parties are also bound to collaborate in an open manner towards the project goals. A steering group is formed with representatives from the main parties with the supporting party’s representatives contributing as expert advisers. But of significance is the organisational shift enabling early involvement of all the main players.

While there is perhaps nothing wrong with the way design, construction and procurement team work today, BIM forces the industry to rethink how projects are delivered. In a traditional project delivery method, there is little high level or strategic collaboration amongst parties: *The owner works with the architect. The owner works with the contractor. The architect works with the contractor. The contractor works with the subcontractors. The project is designed and built.* Linguistically, these sentences are disjointed, and while there is nothing wrong with each sentence independently, they do no flow. The same is true of any type of project; the more collaboration that occurs, the better the flow, and the faster it happens. In a collaborative environment, we may read something like this:

*[The owner, architect, contractor, and subcontractors collaborate, and the project is designed and built.]*³⁷

7.7 Integration & Disintegration

An IPD approach requires contacts to be unifying, cooperative, and complementary agreements designed to foster collaboration and communication and to coordinate and integrate the efforts of the entire team to produce a successful project.³⁸ Many agreements (including the AB family of agreements) used in design and construction tend to have the opposite effect and create adversarial relationships that isolate entities and place them in a position of protecting their own interests over the interests of the other team members and over the interest of the public.

³⁶ Autodesk (2008) *Improving Building Industry Results through Integrated Project Delivery and Building Information Modeling*, Autodesk Whitepaper, Autodesk: California.

³⁷ Waygant, R. (2011) *BIM Content Development: Standards, strategies and best practices*, John Wiley & Sons: New Jersey.

³⁸ Knight, D. (2008) *Teams, Contracts & BIM*, ASHRAE Journal, September 2008.

7.8 Contractual Frameworks – Key Characteristics

7 issues in particular have a profound impact on the mindset of construction project participants as demonstrated through industry tendencies. These tendencies can be considered as a series of phenomena under the following headings:

- ✦ Risk
- ✦ Fees / Reward
- ✦ Responsibility
- ✦ Intellectual Property Rights
- ✦ Legal Liability
- ✦ Insurance
- ✦ Incentives

The table below attempts to categorise these features to articulate the key characteristics and identify the positioning of each contract form reviewed above.

The IPD system allows for a suitably amicable arrangement in all these areas whilst maintaining the primary purpose of engagement; to sustain business and make money. However, the concept of partnering offers an interesting mid-way solution which is gaining ground in Sweden. The AB forms, oriented towards traditional procurement appear to represent a significant hinder to both overall project success and cross-discipline collaboration and co-operation.

Contractual Frameworks – Key Characteristics

Contract	Risk	Fees / Reward	Responsibility	Intellectual Property	Legal Liability	Insurance	Incentives (for project success)	Industry Tendencies
ABK 09	Individually managed, transferred to the greatest possible extent.	Individually pursued; minimum effort for maximum return.	Responsible for professional execution of defined scope of work. Duty of care to discover and resolve any failures in timely fashion.	Consultants often pressurised to 'sign-away' Intellectual Property Rights. Clients insist on being allowed to use the data as they wish.	10 year joint defect liability in connection with consultants design contributions.	Consultants responsibilities insurance required based on contract value. Traditional liability.	Credibility. Bonuses available.	Individuals and companies protect their contribution to the project and project self-importance. Information issued on a need-to-know basis.
AB 04	Individually managed, transferred to the greatest possible extent.	Individually pursued; short-cuts and economies sought at every opportunity; minimum effort for maximum return.	Execution of clients requirements through implementation of consultants designs and documentation.	N/A	10 year defect liability for construction works.	Insurance cover for 1st and 3rd person claims.	Greater profits	Re-work; installation difficulties, blame culture; construction budget and programme overruns.
ABT 06	Individually managed, transferred to the greatest possible extent.	Individually pursued; short-cuts and economies sought at every opportunity; minimum effort for maximum return.	Execution of clients requirements through implementation of consultants designs and documentation.	N/A	10 year defect liability for construction works.	Insurance cover for 1st and 3rd person claims.	Greater profits	Re-work; installation difficulties, blame culture; construction budget and programme overruns.
Partnering	Collectively managed, agreed & monitored thru steering group	Partial sharing project profits; value-based	Collective competencies optimised, project targets articulated All project team members responsible for the success of the project	N/A or as AB family of contracts Use of digital information defined in the BIM Authorised Uses Schedule . Copyright protection for model authors.	ABK 09, AB 04 or ABT 06 are used as as legal basis below the partnering letter of intent	ABK 09, AB 04 or ABT 06 are used as as legal basis below the partnering letter of intent	Partition share in project profits	Use of Partnering is increasing but only within contracting organisations
IPD	Collectively managed, appropriately shared	A portion of remuneration is tied to project success; value-based.	Responsibility for data accuracy defined in the Object Author Matrix .	Use of digital information defined in the BIM Authorised Uses Schedule . Copyright protection for model authors.	Project participants remain responsible for individual scopes of work, IPD approach should not alter traditional approach.	Insurance cover for 1st and 3rd person claims requires tailored to align with scope of IPD duties.	Share in project profits	Individuals care more about the results than their own ego.



Contractual Frameworks – Key Characteristics v1.0 (Hooper, 2011)

Table 2: Contractual Frameworks – Key Characteristics

8.0 Conclusions & Recommendations

8.1 Contractual Hindrances to BIM Collaboration

Significant barriers to BIM collaboration exist in Sweden today. It is clear that there is considerable potential for improvement of construction project organisation, and contractual provisions in connection with the use of BIM technology and implementation methodologies. The standardisation of supporting mechanisms for strategic BIM collaboration may offer a solution to address a number of these barriers.

The results of this study conclude that in Sweden a certain consensus of opinion exists with regards to what are the most important components required to support BIM collaboration and what has the potential to become branch standard.

Today most construction contracts utilise a standard AB form as the basis for engagement. There is nothing to prevent project participants attaching custom-made clauses to supplement these existing contracts and Clients often do. Appending some form of standard BIM-Addendum containing all necessary key supporting concepts may offer a compelling platform for improved strategic BIM-Collaboration and could represent a first step towards a more integrated project delivery.

However, to address the secondary matters of mindset and project organisation (including timing and scope of appointments), a conscious move towards IPD may be necessary. (A separate investigation looking at articulating recommendations regarding the potential of IPD in Sweden has been initiated though SBUF and OpenBIM.) There is a pressure on the industry to adapt contracts that properly facilitate in the increase in effort and collaboration during the early design phases and which permit contractor, specialist subcontractor and supplier input from the outset.

8.2 Barriers & Solutions

This study concludes that although a number of significant barriers or hinders to BIM collaboration exist which to a greater or lesser extend prevent the full potential of BIM being realised in Sweden, the lion's share of them can be effectively addressed in a manner that may reduce or remove them.

A summary of the main findings include:

- ✦ (B):³⁹ Potential for greater branch fragmentation exists as a result of emerging discrete in-house BIM-Manuals.
- ✦ (S): A number of key BIM collaboration supporting mechanisms (often taking different forms within in-house BIM-Manuals) have the potential to become branch standard.
- ✦ (B): Contractors work from BIM data-models produced by consultants at their own risk. If something goes wrong neither the Architect nor Structural Engineers can be held responsible.
- ✦ (S): A responsibility matrix should form part of the appointment documents to support the design and construction team's scope of work.
- ✦ (B): *Approved for construction* 2d paper drawings are still the only legal construction documents.
- ✦ (S): Downstream use of digital data must be considered intelligently by design authors at time of input to enable its use and avoid re-work. Authorised uses of the BIM data should be agreed and recorded with a view to maximise value and downstream use.
- ✦ (B): BIM data-models are not *approved construction documents*. There are no contractual regulations for what legal status digital information has – this is a big risk for quality assurance.⁴⁰

³⁹ (B) = Barrier, (S) = Suggested solution / counter-measure.

⁴⁰ Edgar, J-O. (2008) ByggIndustrin – Issue 34 – *Entreprenörer bygger på egen risk* – Nov 2011 - <http://www.byggindustrin.com> – extracted November 2011.

- ✦ (S): With BIM-Uses, responsibility levels and level of accuracy are established, a clearer picture of the status of that digital information emerges.
- ✦ (B): A broader range of supporting mechanisms is desirable, as branch standard, than those currently available within *Avtal för Digitala Leverancer 2010*.
- ✦ (S): An updated version adopting key supporting mechanisms may go some way towards a more integrated project delivery.
- ✦ (B): Various actors carry uncertainties and unnecessary risk associated with the use of digital information.
- ✦ (S): A branch standard BIM-Addendum would seek to introduce greater clarity of purpose and enable project-based goals to be implemented.

Furthermore, some essential investment is required in simple, standard protocols and service schedules to better define BIM-deliverables, roles & responsibilities and desired outputs. Consistent and cohesive communications are necessary and could be developed and made available to the industry through a neutral organisation such as openBIM.

8.3 Research Questions Re-visited

This study sought to address the following research questions:

- ✦ What is it that hinders BIM collaboration in Sweden?
- ✦ How have other countries attempted to address similar hindrances?
- ✦ What are the key BIM-Support clauses or tools necessary to reduce or remove collaboration hindrances? – Are they applicable in Sweden?
- ✦ IPD presents a new business model that both enables and supports the collaboration at the core of BIM – is there scope for similar models in the Swedish context?

With these questions answered through the preceding analysis, it is clear that through a small number of functioning supporting protocols, potential for greater clarity, more meaningful collaboration and enhanced integration may be realised.

8.4 Recommendations

As an extension of the conclusions, this study proposes 2 sequential recommendations that build on the key findings. These are represented under the following stage headings:

8.6.1 Stage 1: BIM-Collaboration Support Mechanisms

This study firstly recommends that a series of adapted standard protocols are trialled in practice through collaboration with industry organisations. Tuned to national demands, feedback from trials together with industry collaborative workshops would seek to derive synergies in the development of branch standards and protocols and in that way minimises duplication of efforts and allow the leverage of finite resources.

Appropriately drafted standard supporting protocols, together with wider adoption of existing organisational standards may provide a support infrastructure necessary to enable teams to deliver more integrated projects and leverage greater benefits from the use of BIM.

With current knowledge this study recommends an incremental overhaul of contractual provisions to actively support BIM usage. This could start with an updated *Avtal för Digitala Leverancer v.2.0* incorporating the necessary supporting mechanisms mentioned. A draft version could be made available through OpenBIM as an optional appended document. Once thoroughly tested and validated, a standard version published.

The implementation of a branch standard BIM protocol encompassing the features mentioned outside the contract means that a graduated approach to adoption can be realised without the need to redraft contracts. It is recommendable that such progressive steps are taken by the industry, encouraged by existing initiatives such as OpenBIM.

8.4.2 Stage 2: IPD

Further to this it is recommendable that *Byggnadets Kontraktskommitté* (BKK), responsible for the AB family of contracts, closely considers the development of a new standard form of agreement which takes into consideration not just the above mentioned BIM-Supporting mechanisms, but actively facilitates BIM and the IPD collaboration model.

The reason why this should be done now (despite previous discussions on the subject) is that BIM now has a prominent role in the Swedish construction industry, and it is of strategic national advantage (in a global economy) for the sector to have standard contracts with procedural mechanisms that have BIM at its core.

8.5 Summing Up

Whilst there still remains a significant number of technical barriers to BIM adoption and realisation of benefits, contractual hindrances stem from local conditions which, if a consensus of opinion is reached, could be re-crafted to facilitate more effective early collaboration and provide opportunity to formulate project-wide strategic BIM implementation plans.

One thing is clear: with the new technology and processes associated with BIM implementation, new forms of collaboration are inevitable.

Guidance is needed to support teams into making meaningful decisions towards common goals. To this end, this report recommends functional rather than prescriptive specifications; development and publication of guidelines documenting best practice; and an appended BIM-Addendum enabling team decisions to be made on:

- ✦ BIM Delivery Schedule
- ✦ BIM Uses Schedule
- ✦ Level of detail at project stages
- ✦ Model Authorship
- ✦ Model Use Authorisation

Consideration to and collaboration based on these BIM-supporting mechanisms may produce scenarios that remove some of the most stubborn obstacles to BIM collaboration, namely, strategic sharing of intelligent BIM data an ability to work towards common goals *for the good of the project*.

However, on a caution note as Linderoth remarks: *“Because new knowledge is constantly developed and BIM might trigger the industry to re-think the way of organizing and doing business; if this should happen it is important not to lock development into some sort of “best practice” that can be a “worst practice” in the long run”*.⁴¹

It is clear that the Totalentreprenad form has the greatest potential to harness the early contractor involvement necessary for advantageous BIM collaboration. In addition, the relatively non-adversarial nature of the Swedish construction industry is a real boon to the underlying willingness to collaborate.

⁴¹ Linderoth, H. (2011) Linked-In Discussion, OpenBIM Group

For BIM processes to be optimised and common strategic plans to be implemented without undue obstruction, contractual relations must consider putting the design (and BIM-Authoring stages) at the core. BIM solutions can deliver dramatic advances in building technology, but the full potential of BIM will not be achieved without adopting structural changes to existing project delivery.

Fuller collaboration between AEC participants has shown significant gains in project outcomes in terms of both time and cost. By working together to achieve common goals, project teams can optimize output by sharing ideas and delivery solutions with the benefit of diverse perspectives.

Contract types influence the extent to which AEC participants can collaborate. The AB family of contracts in Sweden offer little direct support for BIM collaboration and in this capacity can be considered a hinder. Supporting mechanisms are needed and may be seen as a first incremental step towards IPD.

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Appendix 1: Interviews

Architects & Consultant Engineers

- ✦ Respondent #1: A Major Multi-Disciplinary Engineering Consultant Organisation – IT Development Manager.
- ✦ Respondent #2: A National Architectural & Project Managing Organisation - Architect, Project Manager.
- ✦ Respondent #3: An Architectural Organisation – IT Manager.
- ✦ Respondent #4: A Major Multi-Disciplinary Engineering Consultant Organisation – Civil Engineer, Department Manager.

Contractors

- ✦ Respondent #5: A Major Contractor Organisation – BIM Coordinator
- ✦ Respondent #6: A Major Contractor Organisation – Design Leader

Other Consultations:

- ✦ Construction Advocate Office – Construction Lawyer
- ✦ Facilities Management Organisation – Facilities Manager
- ✦ A Major Contractor Organisation – Head of Virtual Building

Appendix 2: Interview Materials

The questions below were put forward to the reference group to promote awareness and provoke dialog regarding existing contractual hindrances to BIM collaboration and gauge local reaction to the ideas behind IPD. Similar questions were the basis for empirical data collection.

Main Line of Questioning

1. From your experience can you identify (from a user perspective) known and suspected contractual barriers to the use of BIM in connection with the functioning of AB 04 / ABT 06 / ABK 09 / ADL 2010 / E202-2008 / IT manuals.
2. Suggest where you think obstacles to collaboration exist, in particular in relation to:
 - ✦ Downstream transmission of digital information (information exchange).
 - ✦ The ability to create and implement common, project-specific strategic BIM plans.
 - ✦ Successful project coordination.
3. The diagram below suggests a number of key concepts purported to support an integrated delivery process.
 - ✦ Is there an appetite in Sweden to use some of all of these concepts in practice today?
 - ✦ Suggest where you think obstacles to exist in adapting these as branch standards in Sweden.

Templates Used

Factors Hindering BIM Collaboration

Contractual	Technical	Economic	Other (eg social / psychological)



Factors Hindering BIM Collaboration v1.0 (Hooper, 2011)

Figure 15: Factors Hindering BIM Collaboration

Contract Documents – Constituent parts for BIM-Projects

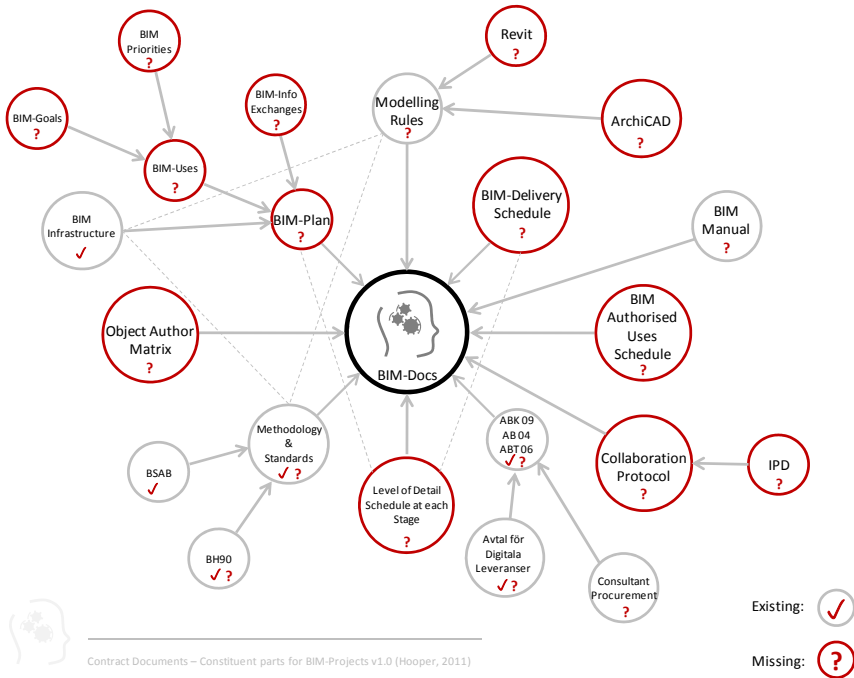


Figure 16: Contract Documents – Constituent parts for BIM-Projects

Terms Used

BIM is an integrated process built on coordinated, reliable information about a project from design through construction and into operations. By adopting BIM, architects, engineers, contractors and owners can easily create coordinated, digital design information and documentation; use that information to accurately visualize, simulate, and analyze performance, appearance and cost; and reliably deliver the project faster, more economically and with reduced environmental impact.

IPD is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction.

Document #1:

**BIM Implementation –
Guidelines for Architects and
Engineers**

Draft guidelines: LTH, Lund, Sweden

Authors: Hooper, M.



BIM-INFO

BIM IMPLEMENTATION – GUIDELINES FOR ARCHITECTS & ENGINEERS

2012



BIM Implementation – Guidelines for Architects & Engineers



LUNDS UNIVERSITET
Lunds Tekniska Högskola

Abstract

Informed by the findings of the research project *BIM Anatomy - An investigation into implementation prerequisites*,¹ **BIM Implementation – Guidelines for Architects & Engineers** - aims to address local Swedish AEC industry requirements for a set of consultant guidelines to complement Bygghandlingar 90² and the FFi's Digitala Informationsleveranser till Förvaltning³. The model for such a guide is based on the buildingSMART Alliance's new *Building Information Modelling Project Execution Planning Guide*.⁴ Developed to be suitable for use in connection with both Swedish and Danish construction projects alike, the new guide suggests a strategic method of BIM implementation through a pedagogical approach to planning and realizing an effectively collaborating information sharing platform, and aims to fill an organisational gap in existing BIM documentation informed by the insights revealed through pilot studies and scientific rigor.

¹ Hooper, M. (2012) *BIM Anatomy - An investigation into implementation prerequisites*, Lund University, Lund.

² SI, Swedish Standards Institute (2008), *Bygghandlingar 90 : byggsektorns rekommendationer för redovisning av byggprojekt*. D. 8, Digitala leveranser för bygg och förvaltning, Stockholm : SIS Förlag AB.

³ FFi (2011) *Digitala Informationsleveranser till och från Förvaltning – Tillämpningsanvisning: FFi – baserad på Bygghandlingar 90 del 8 utgåva 2*, Version 2011, FFi, Sweden.

⁴ Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2010), *Building Information Modelling Project Execution Planning Guide*, Version 2.0, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

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Introduction

This summary document, constituting a set of draft guidelines emanating from the research project and Licentiate Thesis: *BIM Anatomy - An investigation into implementation prerequisites*,⁵ seeks to facilitate an increased level of BIM implementation maturity through a practical set of procedures that can be deployed on a project basis.

Where do these Guidelines fit in?

We consider the place for this set summary guidelines document in the context of:

- ✦ The buildingSMART Alliance Initiatives
- ✦ OpenBIM's national vision

buildingSMART's Vision

To develop and maintain international standards for openBIM including the development of:

- ✦ Processes: IDM
- ✦ Data Dictionary: IFD
- ✦ Data Model: IFC & MVD⁶

These key concepts, though a long way off full integration into AEC workflow, set the scene for things to come. Today simple tools and methods to enable actors to

⁵ Hooper, M. (2012) *BIM Anatomy - An investigation into implementation prerequisites*, Lund University, Lund.

⁶ <http://www.buildingsmart.com/>

participate more fully in BIM processes represent a first step towards a fully automated industry.

OpenBIM's Vision

- ✦ "Focus on the end product - more efficient processes in all areas - competition from developing a common IT platform".
- ✦ "A world in which mutual understanding among the various players and industry-wide definitions are key words in the process of development, and where BIM (building information modelling) is used as a tool to streamline processes on a large scale".⁷

OpenBIM's Objectives

A list of OpenBIM's official objectives is presented below:

To achieve the objectives of the program requires, among other things:

1. **Standardization of frequently occurring processes and / or interfaces between them.**
2. More effective and internationally-based data structures, classifications, concepts, etc.
3. Development of standard contract agreement so that issues such as liability for information ownership, access rights etc adapted to work.
4. Increased information security.
5. For standard and vendor-independent interface for communication.
6. **Processes for greater participation from stakeholders and customers.**
7. **Tools that stimulates job satisfaction, creativity and knowledge and enable intelligent cooperation between different specialists.**
8. **Better support for "building right from the beginning", an improved process that eliminates or greatly reduces the cost rework.**

⁷ <http://www.openbim.se/>

9. **Ability to more easily than with today's technology do simulations and investigate options, to ensure that the best solution was chosen, the different decisions.**
10. Industry-wide metrics that provide an opportunity to see the changes and compare themselves with others (for example, regarding life cycle costs).
11. **Tools and methods that provide better able to:**
 1. **Meet user requirements**
 2. Create good architecture
 3. Create good living environments and urban planning
 4. Comply with financial and technical requirements

This guide aligns harmoniously with the OpenBIM objectives, in particular with those highlighted in **red**.

Purpose & Aims

This guide aims to address local Swedish AEC industry requirements for a set of consultant guidelines to complement and support Bygghandlingar 90.

The model for such a guide is based on the buildingSMART Alliance's new *Building Information Modelling Execution Planning Guide*.

Developed to be suitable for use in connection with Swedish construction projects, it recommends consideration to a common BIM Strategy on a project basis, and is informed by the insights revealed through papers 1-3.

Scope

The guide provides some useful insights into how one might address the issues of BIM implementation, BIM-info management and a quick guide to leveraging the benefits of object-orientated design through delivery of new improved products and services.

The work is subject to clearly formulated arguments and refers to a number of existing BIM 'good idea' documents published around the world and tested in Sweden.

appended as a supporting document. It is informed by insights revealed through Papers #1-3 included within the thesis. (See Figure 1)

Guide Structure

Split into 3 main sections, this guide outlines key constituent parts of a project-specific BIM plan, articulated how to generate an information delivery specification and finally, highlights and reviews a selection of important BIM-supporting mechanisms which may assist in removing obstacles to BIM collaboration.

Part 1: BIM Planning

(A summary of key ideas behind the buildingSMART Alliance's *Building Information Modelling Execution Planning Guide*,⁸ in particular how to create a meaningful BIM-Plan.)

Part 2: Information Delivery Specification

(A development of the concept *Leveransspecifikation*, articulated in BH90)

Part 3: Contractual Support to BIM Collaboration

(Supporting mechanisms to remove or reduce contractual hindrances to BIM collaboration.)

Relation to Research Project

This set of summary guidelines is related to the findings of the research project *BIM Anatomy - An investigation into implementation prerequisites*,⁹ and is

⁸ Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2010), *Building Information Modelling Project Execution Planning Guide*, Version 2.0, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

⁹ Hooper, M. (2012) *BIM Anatomy - An investigation into implementation prerequisites*, Lund University, Lund.

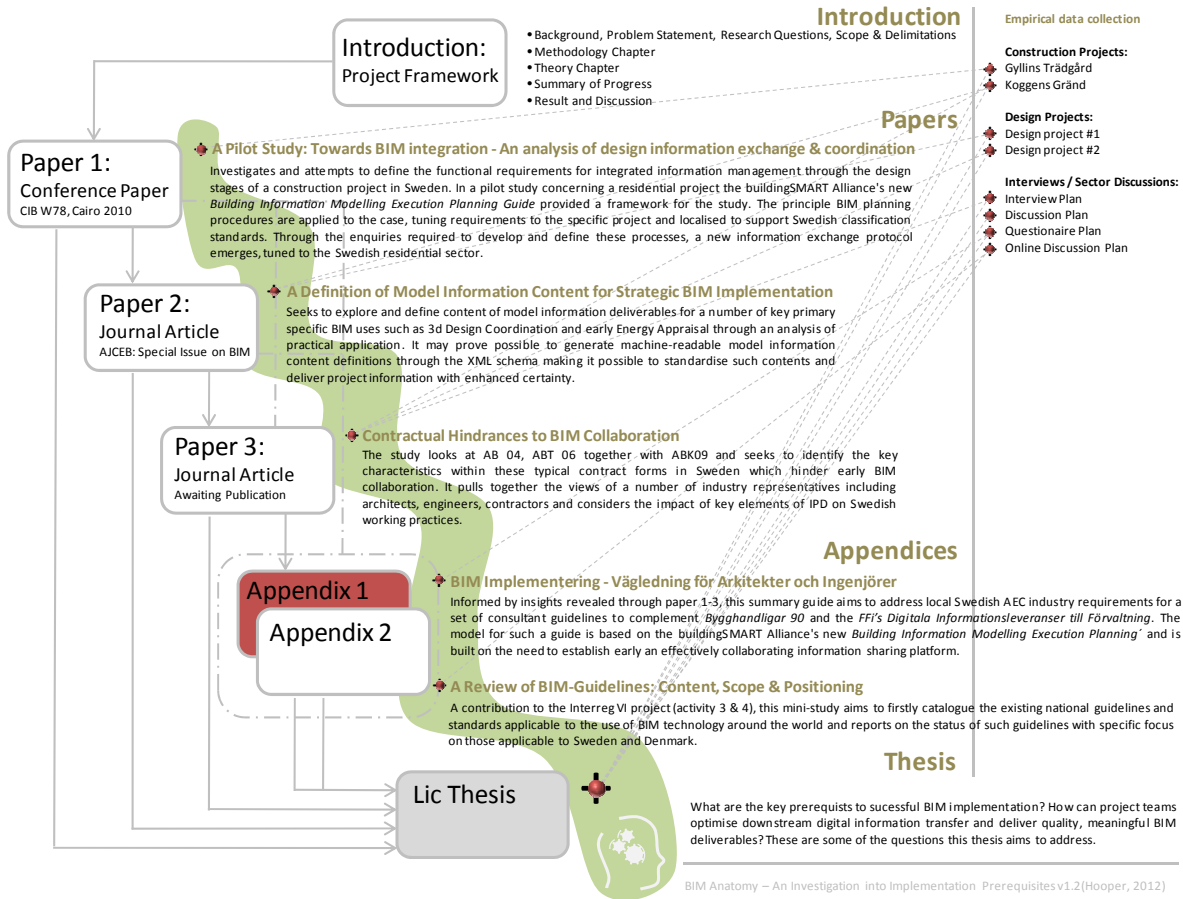


Figure 1: BIM Anatomy – An Investigation into Implementation Prerequisites – Project Plan

Part 1: BIM Planning

A summary of key ideas behind the buildingSMART Alliance's *Building Information Modelling Execution Planning Guide*¹⁰ are presented with a focus on a suggested procedure for creating a meaningful BIM-Plan that may be applied on a project basis.

A BIM-Plan should comprise of 4 action areas, being:

- ✦ Identify Project Goals & BIM Objectives
- ✦ Create BIM Process Design
- ✦ Develop BIM Information Exchanges
- ✦ Define Supporting Infrastructure for BIM Implementation

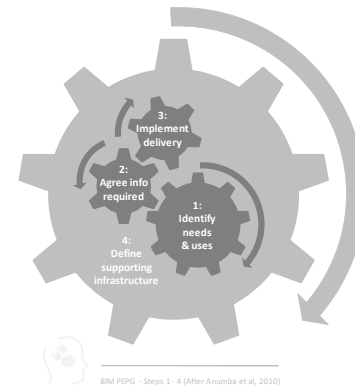


Figure 2: BIM Planning: Steps 1 – 4 (After Anumba et al, 2010)

¹⁰ Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2010), *Building Information Modelling Project Execution Planning Guide*, Version 2.0, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.

Here we focus on the first 3, and assume that the BIM infrastructure is in place. Notwithstanding this, organisations should not neglect to consider and share strategies relating to supporting BIM infrastructure, including:

- ✦ Organisational Roles and Staffing
- ✦ Delivery Strategy
- ✦ Contract Agreements
- ✦ Communication Procedures
- ✦ Technology Infrastructure Needs
- ✦ Model Quality Control Procedures
- ✦ Project Reference Information

A BIM-Plan may provide the basis for dialog amongst project team members and facilitate a method to responding to strategic questions relating to the deployment of BIM technology on design and construction projects. A formal BIM-Plan, agreed and implemented by all project team members, can enable teams to focus on exploiting their BIM resources efficiently.

The BIM-Plan outlined below focuses on information exchanges and a can be executed through a step-by-step planning procedure as follows:

- ✦ Define project and team value through the identification of BIM goals and uses.
- ✦ Develop a process which includes tasks supported by BIM along with information exchanges.
- ✦ Develop the information content, level of detail and responsible party for each exchange.

Step 1: Agree BIM Goals

Here design teams can identify desired *BIM Goals*, allocate each a priority rating and a potential *BIM Use* (See Figure 3). It is essential to identify the specific goals that will provide incentive for implementing BIM on a project basis, with consideration to potential benefits, team competencies and technical resources.

By identifying such goals the design team made a first step in planning for a level of BIM implementation. The definition of project team BIM goals allows individuals to understand each other's contribution and outlines the motivations behind the forthcoming information exchanges.

Next, the identified BIM goals are translated into actual BIM uses. The relationship between BIM goals and uses is interpretive and in which a common understanding and agreement is reached through early collaboration and planning.

Through auditing a capability rating against each BIM use, responsible parties make an objective judgement with regards to their resources, competency and experience - in other words their professional ability to carry through the BIM use (see Figure 4).

Together these parameters lead project teams to decide whether or not to proceed with a proposed BIM use. Aspirational BIM uses can be pursued to test results against traditional methods.

Priority (1-3)	Goal Description	Potential BIM Uses
1- Most Important	Value added objectives	
1	Reduce design failures	3D Design Coordination, Quantity Scheduling
3	Optimise building rational	Phase Planning (4D Modelling), Site Utilization Planning
1	Establish early control of areas / spaces / relationships	Area Scheduling, 3D Design Coordination
3	Manage design / construction information better	Design Authoring
3	Letting out information	Area Scheduling
2	Optimise visualisation output for Planning Submission	Visualisation (Revit - 3D Studio - Rendering - Photoshop)
2	Optimise visualisation output for Client Marketing Material	Visualisation (Revit - 3D Studio - Rendering - Photoshop)
2	Optimise visualisation output for consultants	Visualisation, Design Reviews, 3D Design Coordination
2	Optimise visualisation output for Contractors	Visualisation, Design Reviews, 3D Design Coordination
1	Reduce field conflicts	3D Design Coordination
2	Environmental evaluation	Environmental Analysis (Light / solar studies)
1	Quickly assess cost associated with design changes	Quantity Scheduling, Cost Estimation
3	Facilitate delivery of environmental / sustainability goals	Energy / Engineering Analysis
3	Static stability	Structural Analysis
1	Push forward with BIM in practice - testing possibilities	Various
2	Review design progress	Design Reviews
2	Optimise information delivery to suppliers	Digital Fabrication



BIM Goals Worksheet (After Anumba et al, 2010)

Figure 3: BIM Goals Worksheet – Example

BIM Use*	Value to Project	Responsible Party	Value to Resp Party	Capability Rating			Additional Resources / Competencies Required to Implement	Notes	Proceed with Use
				Resources	Competency	Experience			
	High / Med / Low		High / Med / Low	Scale 1-3 (1 = Low)					YES / NO / MAYBE
Digital Fabrication	Med	SE	Low	1	1	1		Roof trusses	Yes
		MEP	Low	2	2	2		Ventilation ductwork / installation	
		C	High	2	2	2			
3D Design Coordination	High	A	High	3	3	2			Yes
		MEP	High	3	3	2			
		SE	High	1	1	1	Training in Revit required	Revit coordination & 2d dwg	
Design Authoring	High	A	High	3	3	3		2D / 3D communication / info	Yes
		MEP	High	3	2	2			
		SE	High	2	2	2			
Sustainability Evaluation	High	A	High	1	1	1	Training in IES VE required	Miljöbyggprogram SYD	No
		MEP	High	2	2	2			
		Owner	High	1	1	1			



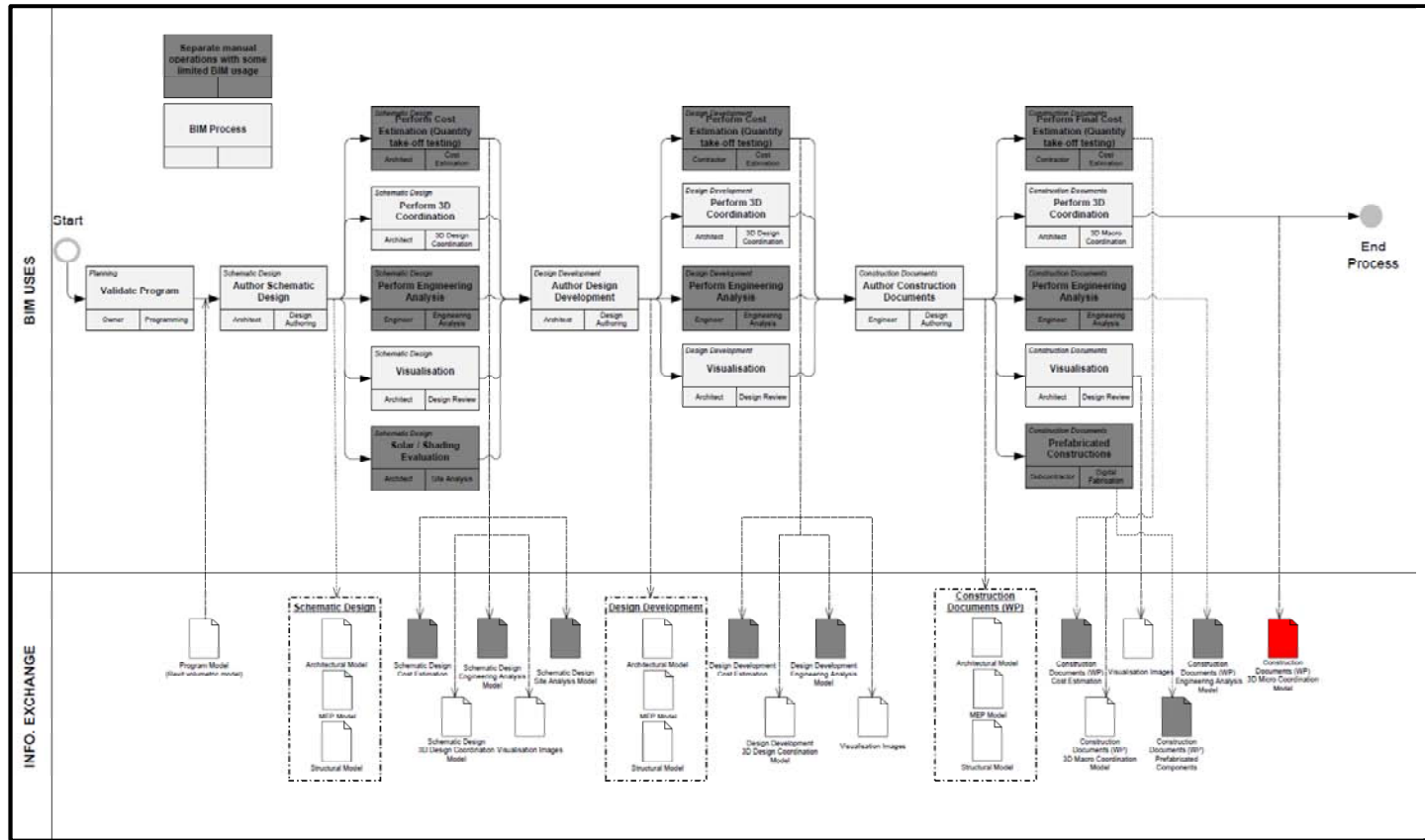
BIM Uses Analysis Worksheet (After Anumba et al, 2010)

Figure 4: BIM Use Analysis Worksheet – Example

Step 2: Design BIM Project Execution Process

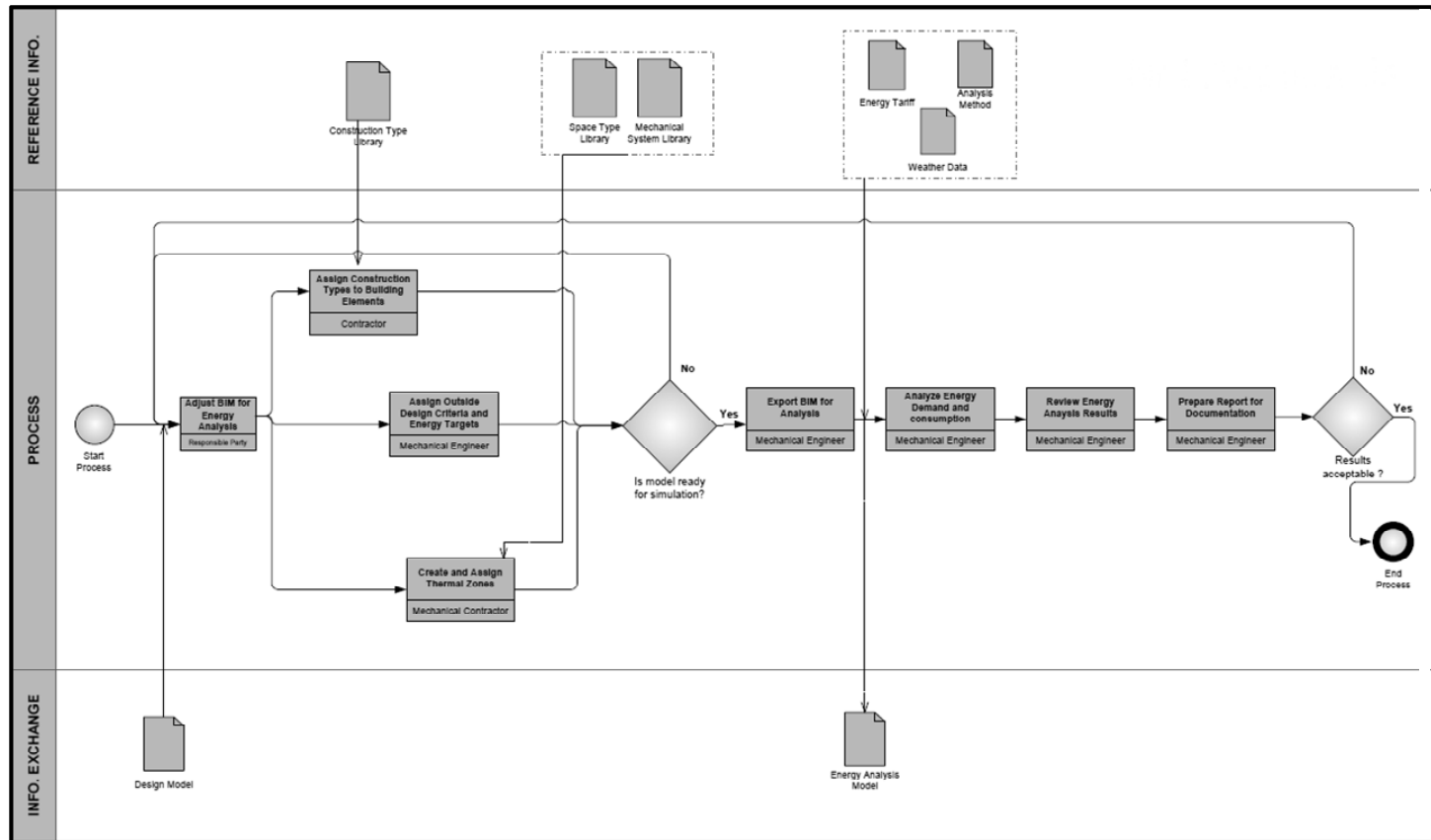
Once the team has identified the specific BIM Uses, a process mapping procedure for planning the BIM implementation can be performed. A high level map showing the sequencing and interaction between the primary BIM Uses on the project can be developed. This allows all team members to clearly understand how their work processes interact with the processes performed by other team members. First the high level map is developed, then more detailed process maps can be added by the team members responsible for each detailed BIM use. The high level map (see Figure 5) shows how *BIM authoring*, *energy modelling*, and *cost estimating*, are sequenced and interrelated. The secondary detailed maps records the detailed processes that will be performed by an organisation or in some cases several organisations, such as the energy modelling (see Figures 6 & 7).

Engaging the design team in this process goes some way to determining the 'who' and 'when' questions relating to information exchange.



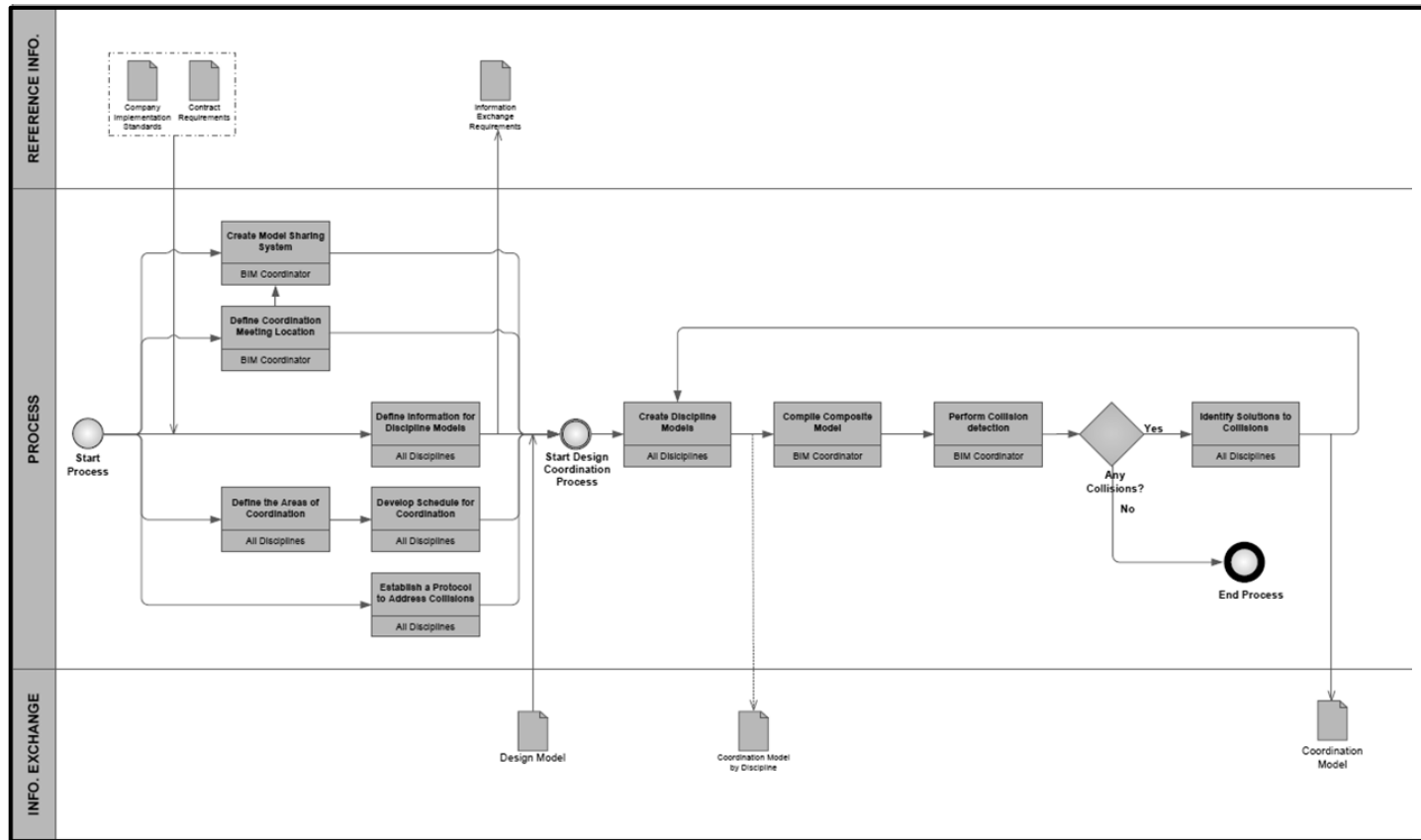
BIM Information Exchange Worksheet (After Anumba et al, 2010)

Figure 5: BIM Execution Process Map (Overview) – Example



BIM Information Exchange Worksheet – Energy Analysis (After Anumba et al, 2010)

Figure 6: BIM Information Exchange Worksheet – Energy Analysis - Example



BIM Information Exchange Worksheet – Design Coordination (After Anumba et al, 2010)

Figure 7: BIM Information Exchange Worksheet – Design Coordination - Example

Step 3: Develop Information Exchange Requirements

Once the appropriate process maps have been developed, the information exchanges which occur between the project participants can be identified. It is important for the team members, in particular the author and receiver for each information exchange transaction, to understand the information content.

This information content for the exchange is defined in the *Information Exchange* table (see Figure 8). Here, consultants can develop a chart mapping information exchange content, level of detail and responsible party for each exchange. This procedure identifies the vital information required to implement each BIM Use as defined previously.

BIM Use Title		Design Authoring (Schematic Design)			Cost Estimation			3D Coordination			Design Reviews			Energy Analysis		
Project Phase		Design			Design			Design			Design Reviews			Design		
Time of Exchange (SD, DD, CD, Construction)		SD			SD			SD			SD			SD		
Responsible Party (Information Receiver)		A, SE, MEP			Cost Consultant			A, SE, MEP			A, SE, MEP			Energy Consultant		
Receiver File Format		Revit *.rvt Acad *.dwg						Navisworks *.nwd			Navisworks *.nwd			Acad *.dwg		
Application & Version		Revit V.10, Acad, MagiCad						Navisworks V.10			Navisworks, PowerP			VIP +		
Model Element Breakdown		Info	Resp Party	Additional Information	Info	Resp Party	Notes	Info	Resp Party	Notes	Info	Resp Party	Notes	Info	Resp Party	Additional Information
A	SUBSTRUCTURE															
	Foundations															
	Standard Foundations	A	A/SE		A	A/SE		A	A/SE		A	A/SE				
	Special Foundations	A	A/SE		A	A/SE		A	A/SE		A	A/SE				
	Slab on Grade	A	A/SE		A	A/SE		A	A/SE		A	A/SE				
	Basement Construction															
	Basement Excavation	A	A/SE		A	A/SE		A	A/SE		A	A/SE				
	Basement Walls	A	A/SE		A	A/SE		A	A/SE		A	A/SE				
B	SHELL															
	Superstructure															
	Floor Construction	A	A		A	A		A	A		A	A		A	A	
	Roof Construction	A	A		A	A		A	A		A	A		A	A	
	Exterior Enclosure															
	Exterior Walls	A	A		A	A		A	A		A	A		A	A	
	Exterior Windows	A	A		A	A		A	A		A	A		A	A	
	Exterior Doors	A	A		A	A		A	A		A	A		A	A	
	Roofing															
	Roof Coverings	A	A		A	A		A	A		A	A		A	A	
	Roof Openings	A	A		A	A		A	A		A	A		A	A	



BIM Execution Process Map (Level 1) (After Anumba et al, 2010)

Figure 8: Extract from: BIM Information Exchange Worksheet - Example

Part 2: Information Delivery Specification

A development of concept of *Leveransspecifikationer* (Delivery Specification) described in *Bygghandlingar 90*,¹¹ the process outline below may be deployed to support information exchange requirements and align consultant's information delivery expectations on BIM projects.

The BIM-Info Delivery Protocol (IDP) is presented below as a sequence of pedagogical steps designed to respond to the need to create greater certainty around digital information deliveries (Figure 9).

The procedure aims to enable users to methodically articulate and record information flow and priorities in standard way and reduce the risk for misunderstanding, waste and re-work.

¹¹ SI, Swedish Standards Institute (2008), *Bygghandlingar 90 : byggsektorsrekommendationer för redovisning av byggprojekt*. D. 8, Digitala leveranser för bygg och förvaltning, Stockholm : SIS Förlag AB.

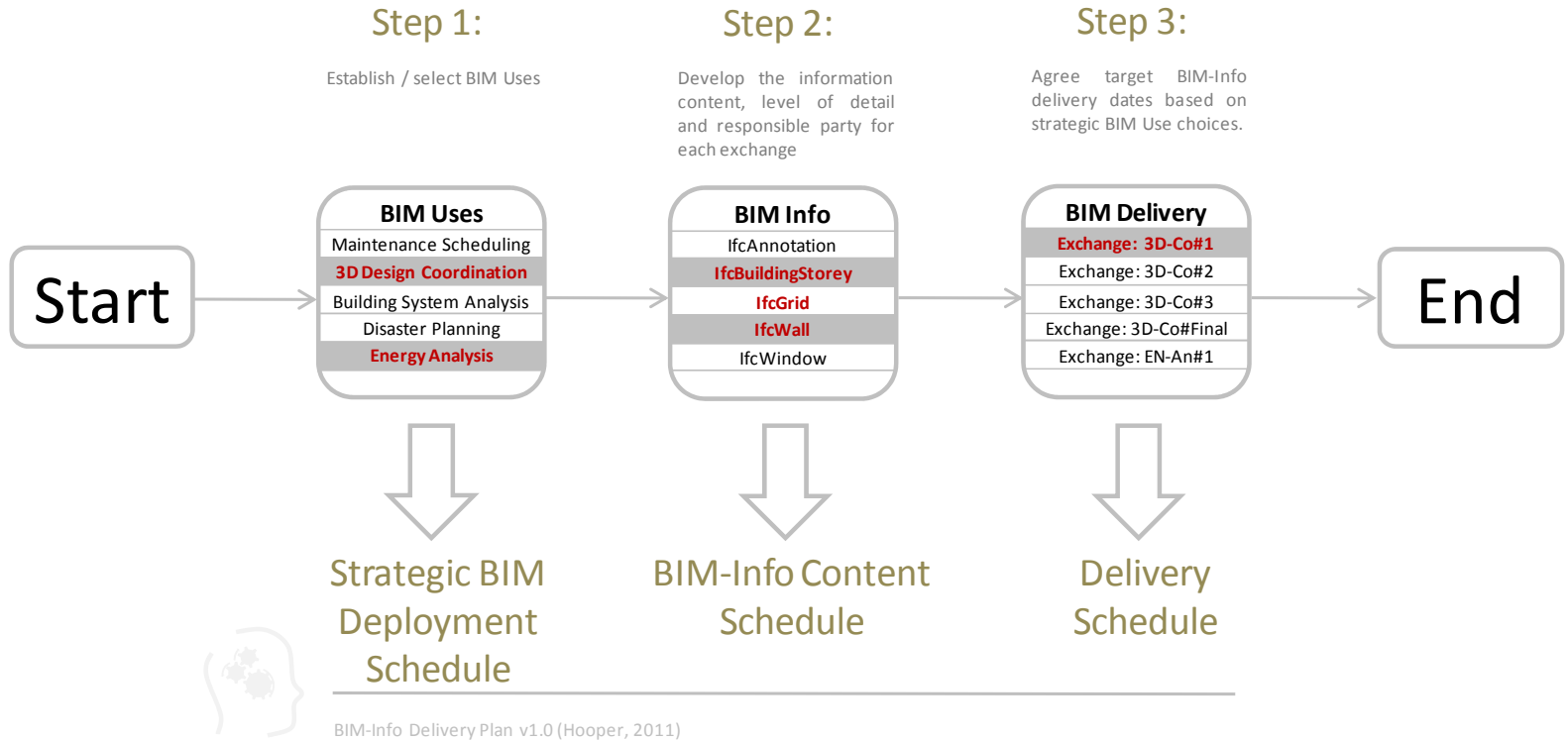


Figure 9: BIM-Info Delivery Protocol

Step 1: BIM-Uses

Teams must establish at the outset the strategic BIM-Uses they wish to deploy on a project specific basis.



Figure 10: Example BIM-Uses

The decision to implement a BIM-Use must be based on resources, competency and anticipated value to the project. Against each BIM-Use members should consider and articulate the timing of such activities through the BIM-Authoring stages to enable focus on imminent information demands and optimize information flow. The figure below illustrates how this might be articulated whilst enabling efficient implementation.

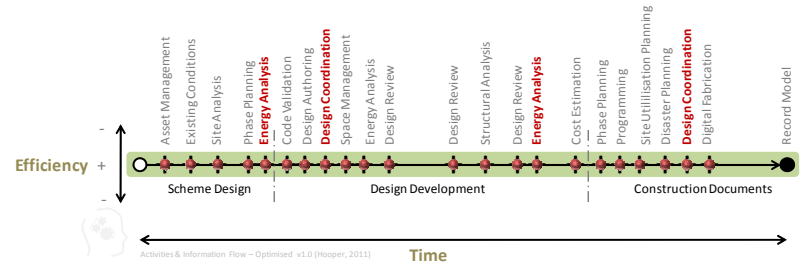


Figure 11: Activities & Information Flow – Optimised

Often overlooked, there is common business sense to the idea that, if certain design information can be supplied at right time then its value to the project can be optimized. BIM-Uses should be selected for the right reasons – as drivers to the process and to help provide the data to support strategic decisions along the way.

Step 2: BIM-Info

Here a definition of the model information content for strategic BIM implementation is articulated through scheduling the key objects with associated level of detail and responsible party. A BIM-Info Delivery Specification (IDS) template can be used to express the information content and exchanges necessary to carry out and efficiently implement a specific BIM-Use.

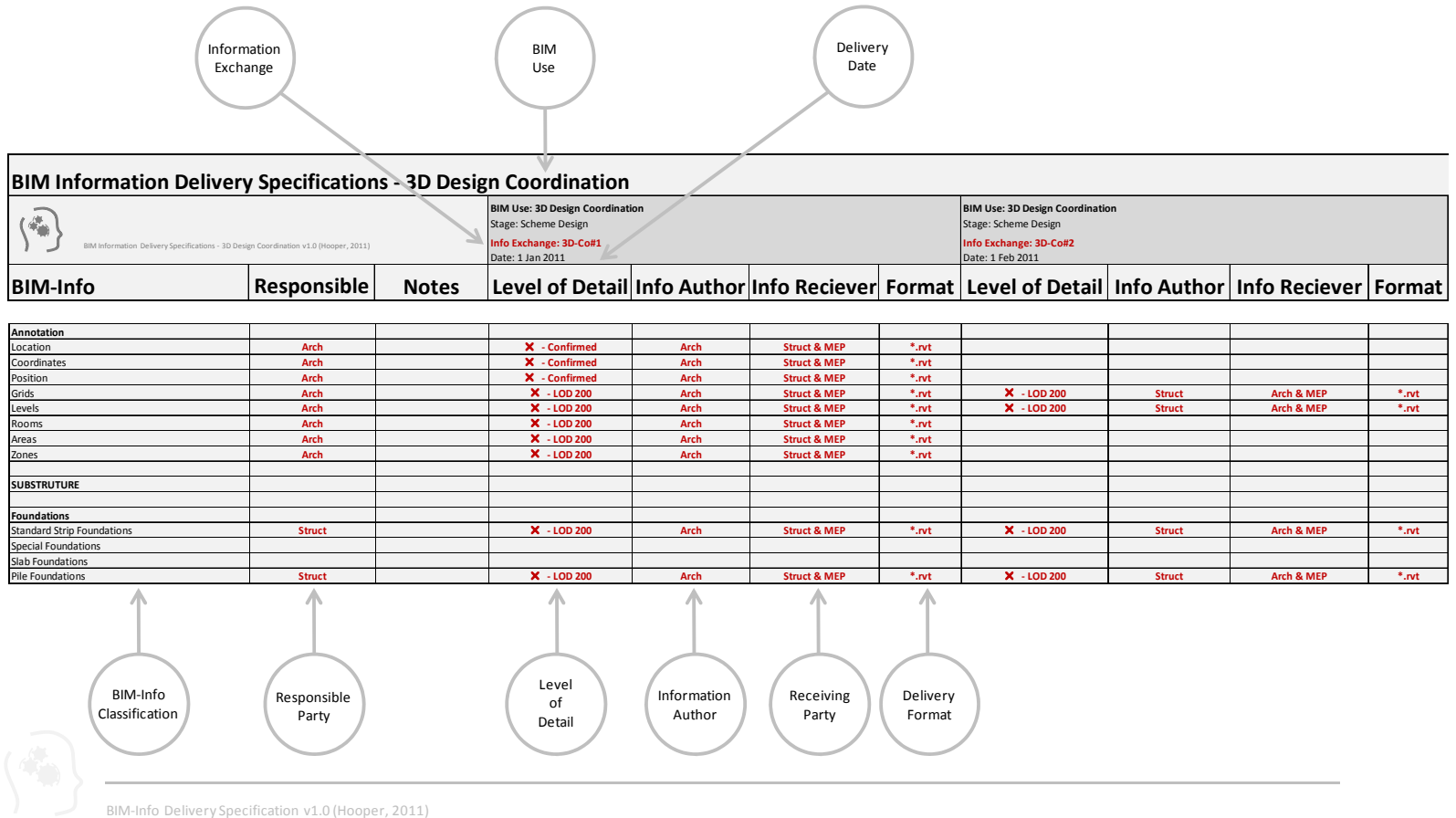


Figure 12: BIM Information Delivery Specification

Step 3: BIM-Delivery

Registry of BIM-Info exchanges can be readily recorded and communicated through project networks in accordance with the delivery schedule. However, often neglected is a sub-process of quality control. This is necessary more than ever – not least to demonstrate due diligence – but to ensure the content of BIM-Info Deliveries match with the general expectations of the project team as articulated in the BIM-Info Delivery Specification schedule. This process is essential to eliminate rework for receivers and puts the onus on the supplier to ensure the contents is what it says it is.



Figure 13: BIM-Info Content Quality Control Measures

Part 3: BIM Collaboration Support

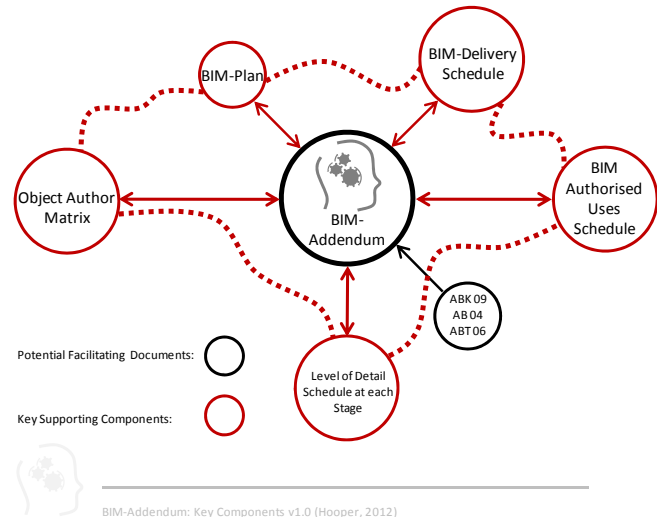


Figure 14: BIM-Addendum: Key Components

The BIM-Addendum includes the following 5 components:

To support collaboration centred on the use of BIM and sharing digital information, a number of key supporting mechanism may have application on BIM projects. The BIM-Addendum outlined below can help organisations define the parameters of the project’s digital information exchange, articulate how it shall be managed and specify any restrictions.

- ✦ Project-based BIM-Plan (including identification of common project goals, BIM-Uses etc, as described in section 1 above)
- ✦ Object Author Matrix
- ✦ Level of Detail Schedule at each Stage
- ✦ BIM-Delivery Schedule
- ✦ BIM Authorised Uses Schedule.

Project-based BIM-Plan: key to sorting out objectives, a strategic BIM-Plan should set out the project team’s BIM goals, uses, resources to be deployed, and planning for information exchanges through the project. Table 1 can be used to articulate planned BIM-Uses in connection with a BIM-Plan).

Object Author Matrix: enables teams to readily identify and be certain over *responsible party* for authoring and maintaining the correctness of *BIM content* and *status* of objects. Both variables are expected to change through the life of an object, a standard method is needed to record this to remove doubt and facilitate clarity (Table 2).

Level of Detail Schedule at each Stage: intended to provide clients with an overview of the expected or attainable level of development at key project milestones, it can also be used to help align design consultants’ BIM authoring patterns and determine strategic points in time to deploy BIM-Uses, and nD applications¹² (Table 3).

BIM-Delivery Schedule: generally part of the *BIM-Plan* and related to the *information delivery specification*, this part enables standard articulation of what to deliver, when based on BIM-Uses and responsible party (Table 4).

BIM Authorised Uses Schedule: authorised use of digital information is a key matter on which earlier agreement can be advantageous. Here it is suggested that since a model can potentially be used for a raft of different uses (costing, scheduling, performance simulation, code checking, and visualization, to name just a few), it seems obvious that the author of the model should define the suitability of the model for a particular use. Authorised uses of the BIM data should be agreed and recorded with a view to maximise value and downstream use (Table 5).

The tables below can be used to agree and articulate project-based decisions under these fore mentioned categories.

¹² nD: n-Dimensional where n is a number. Recognised examples are 3D Design Coordination, 4D Construction sequencing, 5D Cost Analysis, 6D Facilities Management, nD Energy Simulation.

Table 1: BIM-Uses Schedule

Envisaged Models by BIM-Use	Main Author	Proprietary Software Tool	Max LOD
eg Early Energy Appraisal Model	Architect	Revit Architecture + Green Building Studio	+LOD: 300



BIM-Uses Schedule v1.0 (Hooper, 2011)

Table 1: BIM-Uses Schedule

Table 2: Object Author Schedule

BIM-Info (By construction classification)	Max LOD	Info-Author	Notes
GENERAL			
Project Information		Architect	
Project Issue Date	↗LOD: ###		
Project Status	↗LOD: ###		
Information Status	↗LOD: ###		
Client Name	↗LOD: ###		
Project Address	↗LOD: ###		
Project Name	↗LOD: ###		
Project Number	↗LOD: ###		
Project Units		Architect	
Length	↗LOD: ###		
Area	↗LOD: ###		
Volume	↗LOD: ###		
Angle	↗LOD: ###		
Slope	↗LOD: ###		
Currency	↗LOD: ###		
Annotation		Architect	
Location	↗LOD: ###		
Coordinates	↗LOD: ###		
Position	↗LOD: 400		
Grids	↗LOD: 400		
Levels	↗LOD: 400		
Rooms	↗LOD: 400		
Areas	↗LOD: 400		
Zones			
SUBSTRUCTURE			
Foundations		Architect	
Standard Strip Foundations			
Special Foundations	↗LOD: 200		
Slab Foundations	↗LOD: 200		
Pile Foundations	↗LOD: 200		
Basement Construction		Architect	
Basement Excavation	↗LOD: 200		
Basement Walls	↗LOD: 200		
Backfill			
SHELL			
Superstructure		Architect	
Ground Floor Construction	↗LOD: 400		
Ground Floor Slab	↗LOD: 400		
Upper Floor Construction	↗LOD: 400		
Roof Construction	↗LOD: 400		
Steel Frame	↗LOD: 400		
Bracing	↗LOD: 400		
Shafts & Built-in Ducts	↗LOD: 400		
Voids for in structure for services	↗LOD: 400		



Object Author Schedule v1.0 (Hooper, 2011)

Table 2: Object Author Matrix (Extract)

Table 3: Level of Detail at Project Stages

Models by BIM-Use	Design Phases Projekteringsfaser				Construction Phases Byggsfaser		FM Phases Förvaltningfaser	
	Investigations Utredningar	Programme Programhandling	Concept Design Förslagshandling	Technical Design Huvudhandling / Systemhandling	Construction Docs Bygghandlingar	Construction Relationshanlingar	As-Built Documentation Relationshanlingar	Operation & Maintenance Drifhandlingar & Underhållshandlingar
➤ Space Programme Model	➤LOD: 100	➤LOD: 200		➤LOD: 300		➤LOD: 400		➤LOD: 500
➤ Maintenance Scheduling	➤LOD: 100		➤LOD: 200	➤LOD: 300			➤LOD: 400	➤LOD: 500
➤ Building System Analysis	➤LOD: 100	➤LOD: 200		➤LOD: 300		➤LOD: 400		
➤ Asset Management	➤LOD: 100		➤LOD: 200	➤LOD: 300			➤LOD: 400	➤LOD: 500
➤ Space Management / Tracking	➤LOD: 100		➤LOD: 200		➤LOD: 300		➤LOD: 400	➤LOD: 500
➤ Disaster Planning								
➤ Record Modelling	➤LOD: 100	➤LOD: 200		➤LOD: 300			➤LOD: 400	➤LOD: 500
➤ Site Utilization Planning								
➤ Construction System Design								
➤ Digital Fabrication								
➤ 3D Control and Planning								
➤ 3D Design Coordination								
➤ Design Authoring								
➤ Energy Analysis								
➤ Structural Analysis								
➤ Lighting Analysis								
➤ Mechanical Analysis								
➤ Other Eng. Analysis								
➤ LEED Evaluation								
➤ Code Validation								
➤ Programming								
➤ Site Analysis								
➤ Design Reviews								
➤ Phase Planning (4D Modelling)								
➤ Cost Estimation								
➤ Existing Conditions Modelling								



Level of Detail at Project Stages v1.0 (Hooper, 2011)

Table 3: Level of Detail at Project Stages

Table 4: BIM-Deliverables

Models by BIM-Use	Main Author	Proprietary Software Tool	Target Completion Date (with summary of results)
eg Early Energy Appraisal Model	Architect	Revit Architecture + Green Building Studio	1 August 2012



BIM-Deliverables Schedule v1.0 (Hooper, 2011)

Table 4: BIM-Deliverables

Table 5: Authorised Uses Schedule

Models by Author	LOD	Authorised Downstream Uses
Architect	◆ LOD: 300	<ul style="list-style-type: none"> ◆ Maintenance Scheduling (6D) ◆ Building System Analysis ◆ Asset Management ◆ Space Management / Tracking ◆ Disaster Planning ◆ Record Modelling ◆ Site Utilization Planning ◆ Construction System Design ◆ Digital Fabrication ◆ 3D Control and Planning ◆ 3D Design Coordination ◆ Design Authoring ◆ Energy Analysis ◆ Structural Analysis ◆ Lighting Analysis ◆ Mechanical Analysis ◆ Other Eng. Analysis ◆ LEED Evaluation ◆ Code Validation ◆ Space Programming ◆ Site Analysis ◆ Design Reviews ◆ Phase Planning (4D Modelling) ◆ Cost Estimation(5D) ◆ Existing Conditions Modelling



Authorised Use Schedule v1.0 (Hooper, 2011)

Table 5: Authorised Uses Schedule

References

Documents:

- ✦ Anumba, C., Dubler, C., Goodman, S., Kasprzak, C., Kreider, R., Messner, J., Saluja, C., Zikic, N. (2010), *Building Information Modelling Project Execution Planning Guide*, Version 2.0, The Computer Integrated Construction Research Group, The Pennsylvania State University, Pennsylvania, USA.
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Web:

- ✦ OpenBIM: <http://www.openbim.se/>
- ✦ buildingSMART: <http://www.buildingsmart.com/>
- ✦ BIM Execution Planning : <http://bim.psu.edu/>

Martin Hooper

Oct 2011



LUNDS UNIVERSITET
Lunds Tekniska Högskola

Document #2:

**A Review of BIM-Guidelines:
Content, Scope & Positioning**

Mini-study: LTH, Lund, Sweden

Authors: Hooper, M.



2012

INTERREG IV

A REVIEW OF BIM-GUIDELINES: CONTENT, SCOPE & POSITIONING

A Review of BIM-Guidelines: Content, Scope & Positioning



LUNDS UNIVERSITET
Lunds Tekniska Högskola

Abstract

A contribution to the Interreg IVa Project (activity 3 & 4)¹, this mini-study aims to firstly catalogue the existing national guidelines and standards applicable to the use of BIM technology around the world and reports on the status of such guidelines with specific focus on those applicable to Sweden and Denmark.

This study reveals significant dislocation between national BIM guidelines and highlights a risk for divergence of standards and BIM working methodology in Sweden. It also has helped identify deficiencies (what is missing) in the context of world best practice documentation in Sweden.

¹ The Interreg IV Projekt: Integrering av hållbara Byggprocesser is an EU funded project which amongst other things looks into the harmonisation of Swedish and Danish BIM Implementation Standards.. See <http://www.interreg-oks.eu/se>

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Introduction

This mini-study attempts to report through graphic representation, a review of BIM-Guidelines, including specifically their *content*, *scope* and *positioning*.

It represents a summarised state of the art inventory of BIM guidelines and focuses on guides sourced from:

- ✦ Sweden
- ✦ Nordics
- ✦ World

It considers a categorization of selected guideline documents including:

- ✦ Administrative
- ✦ Strategic
- ✦ Contractual

And aims to reveal what's missing in Sweden with regards guidelines and supporting documentation to support BIM use.

Discussions and deeper clarifications of the meaning and implications of this report can be found in sections 4.1.4, 4.4 and 5.1.1 of the Licentiate Thesis: *BIM Anatomy - An investigation into implementation prerequisites*² however, the content here is largely self-explanatory.

² Hooper, M. (2012) *BIM Anatomy - An investigation into implementation prerequisites*, Lund University, Lund.

A Review of BIM-Guidelines

Content, Scope & Positioning

Main objectives of most BIM guideline documents:

- ✦ To instruct AEC audience in best practice.
- ✦ How to handle the creation or use of BIM data.
- ✦ How to improve effectiveness and efficiency of activities throughout the DCO lifecycle.
 - ✦ How to implement BIM processes.

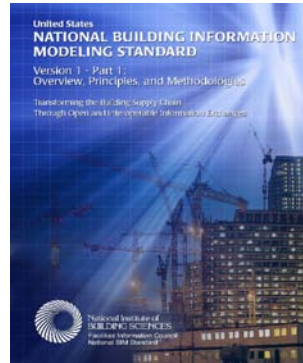
The main aim of the organizations behind them is to improve the ability to **communicate, re-use and share data efficiently without loss, contradiction or misrepresentation** during the lifecycle of a facility.

BIM Patterns: A spotlight on selected BIM Standards & Guidelines worldwide



Figure 1: BIM Patterns: A spotlight on selected BIM Standards & Guidelines worldwide

NBIMS (US)



Key Features:

- ✦ National Standard (foundation)
 - ✦ Foundation related to goals & activities of the BuildingSMART.
- ✦ Intention to improve the DCO process using standardized, machine-readable information.
 - ✦ Most conceptual
 - ✦ Intended to be the first of many parts.
- ✦ Little attempt has been made to adopt the principles in the US.

“Although many American companies are at the forefront of BIM software use, the sheer size of the construction industry makes altering course towards a universal acceptance of BIM difficult. This is not helped by the culture of litigation and large damages claims”.³

³ *Ten truths about BIM – The most significant opportunity to transform the design and construction industry* (WSP & Kairos Future 2011).

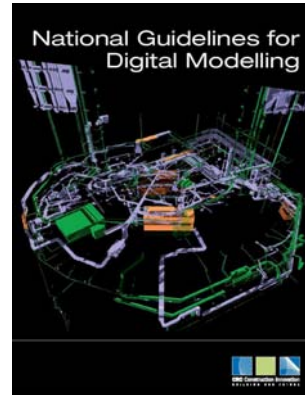
AIA Document E202 – 2008 (US)



Key Features:

- ✦ Contractual status
- ✦ Key strategic BIM decisions
- ✦ Collaboration parameters
- ✦ Compatible with IPD philosophy
 - ✦ Key concepts:
 - ✦ Level of detail schedule
 - ✦ Authorized uses
 - ✦ Object author matrix
 - ✦ BIM deliverables

NGDM (Aus)



Key Features

- ✦ Intention to motivate industry towards BIM use.
 - ✦ Simplified, down to earth language.
 - ✦ Summarized mainstream concepts.
 - ✦ Case studies appendix.
 - ✦ Multi-discipline appeal.
 - ✦ Lacking tangible tools.

“BIM is starting to take off, but governments and industry associations are being urged to help speed up the process. The Sydney Opera House is a shining example of how BIM is used in the management of existing buildings”.⁴

⁴ *Ten truths about BIM – The most significant opportunity to transform the design and construction industry* (WSP & Kairos Future 2011)

AEC BIM Standard (UK)



Key Features

- ✦ Intention to improve process of design information production, management & exchange.
 - ✦ One of several documents, not integrated.
 - ✦ Appendices application specific.
 - ✦ Private initiative.
 - ✦ Lacking tangible examples & solutions

“The UK construction industry has less enthusiasm for BIM than some other countries discussed. Its government’s decision to make BIM part of its procurement policy has met with some scepticism. There is little interest about the software”.⁵

Senate Properties BIM Requirements (FIN)



Key Features:

- ✦ Multi-volume guide.
- ✦ Discipline specific appendices.
- ✦ Intention to develop customer-orientated & cost-effective working method.
- ✦ Compulsory use on state projects.
- ✦ Both strategic & administrative

“The adoption of BIM in Finland is further advanced than anywhere else in the world. Finland is a technologically advanced nation with a small, agile construction industry and a long history of trust and open standards – the perfect environment for BIM to thrive. It is often used on small-scale projects”.⁶

⁶ *Ten truths about BIM – The most significant opportunity to transform the design and construction industry* (WSP & Kairos Future 2011)

Statsbygg BIM Manual (NO)



Key Features:

- ✦ The result of government initiative.
- ✦ Compulsory use for state projects.
- ✦ Guidelines for BIM in projects and the property asset management.
 - ✦ Based on experiences and feedback on previous versions.
 - ✦ Strong on strategic planning.

“A small construction industry and a government, regulatory bodies and the construction industry all actively promoting the use of BIM, have combined to make Norway a BIM success story. It’s essential for all major infrastructure and government building projects. It’s even being taught in school”.⁷

⁷ *Ten truths about BIM – The most significant opportunity to transform the design and construction industry* (WSP & Kairos Future 2011)

Bygghandlingar 90 (Swe)



Key Features

- ✦ Administrative guidelines.
- ✦ A development of traditional working method.
- ✦ Some aspects abstract & conceptual.
- ✦ Often referred to but of little importance.
 - ✦ Lacks concrete examples.
 - ✦ Lacks strategic insight.

“Sweden is catching up with Finland and Norway and in particular is leading the field in using BIM to design and build large and complex infrastructure projects, such as the Stockholm Bypass and the new City Line in Stockholm. In 2009 the OpenBIM organization was launched to establish BIM standards in Sweden”.⁸

⁸ *Ten truths about BIM – The most significant opportunity to transform the design and construction industry* (WSP & Kairos Future 2011)

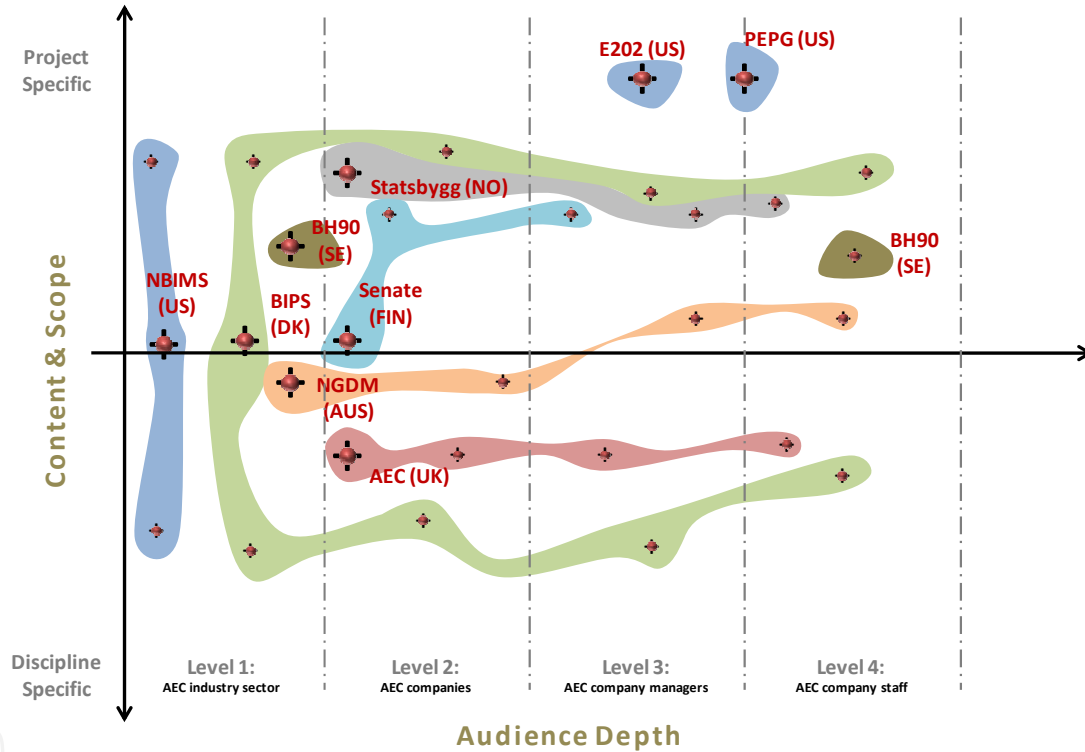
BIPS (DK)



Key Features

- ✦ Commission by Digital Construction – government initiative.
 - ✦ Multiple documents including:
 - ✦ 3D Working Methods
 - ✦ 3D CAD Manual
 - ✦ Object Structures
 - ✦ Covers all audience levels
- ✦ Intention to improve efficiency & quality of design
 - ✦ Comprehensive package.

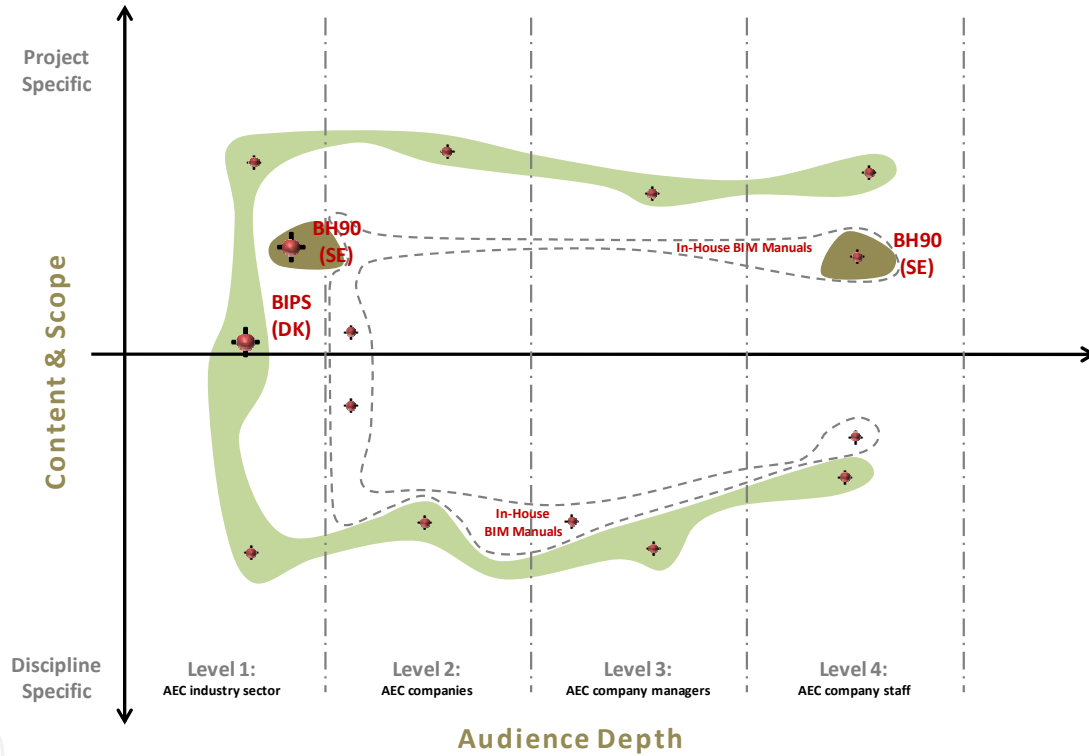
BIM-Guidelines: Positioning



Audience Depth v. Content & Scope (After Gobar Adviseurs, 2010)

Figure 2: BIM-Guidelines: Positioning (Audience Depth v. Content & Scope)

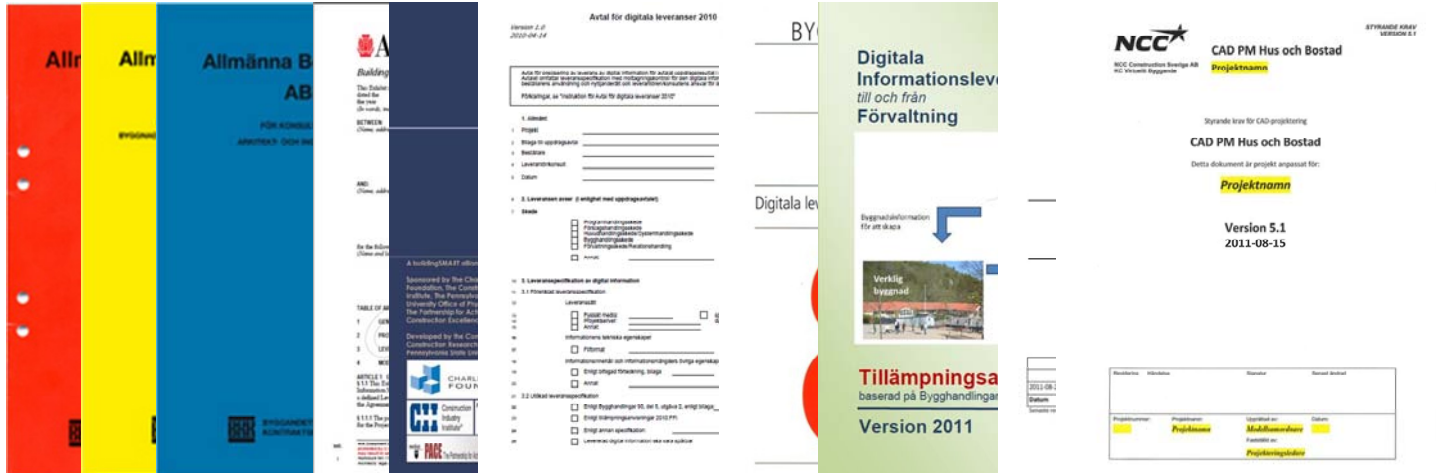
BIM-Guidelines: Positioning



DK / SE BIM Guidelines: Positioning v1.0 (Hooper, 2011)

Figure 3: DK / SE BIM Guidelines: Positioning (Audience Depth v. Content & Scope)

BIM-Docs: Sweden



Contract Docs

Appended BIM-Supporting Docs

Digital Info Guides

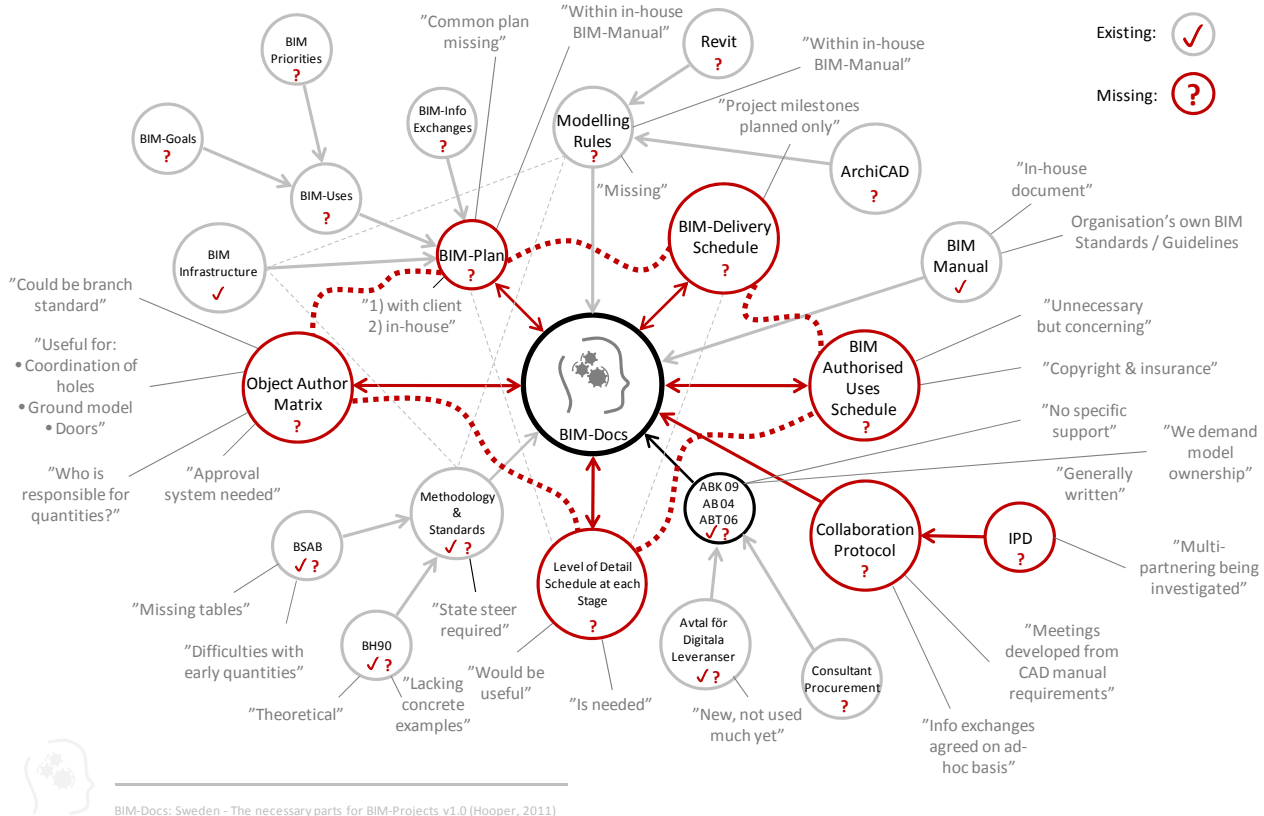
In-house Manuals



BIM-Docs: Sweden v1.0 (Hooper, 2011)

Figure 4: BIM-Docs: Sweden

BIM-Docs: Sweden - The necessary parts



BIM-Docs: Sweden - The necessary parts for BIM-Projects v1.0 (Hooper, 2011)

Figure 5: BIM-Docs: Sweden – The necessary parts for BIM-Projects

BIM-Docs: Sweden - Administrative & Strategic

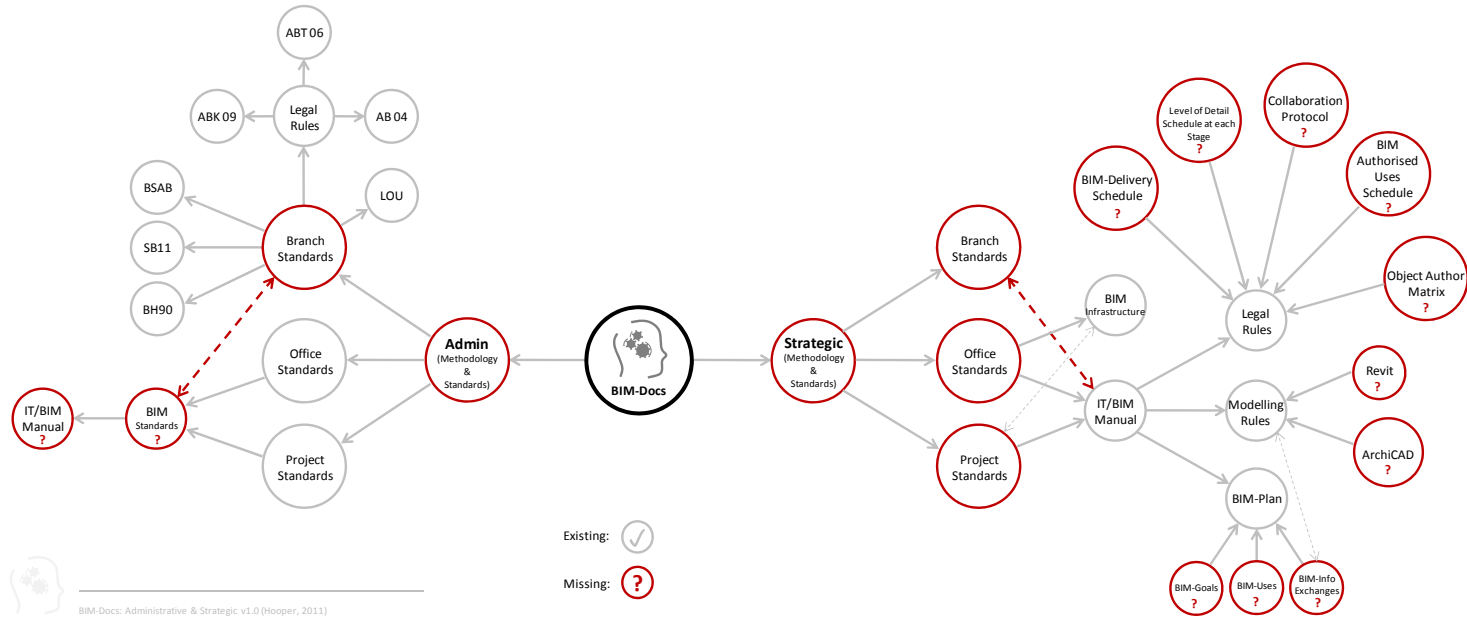


Figure 6: BIM-Docs: Administrative & Strategic

BIM-Platforms: DK & SE

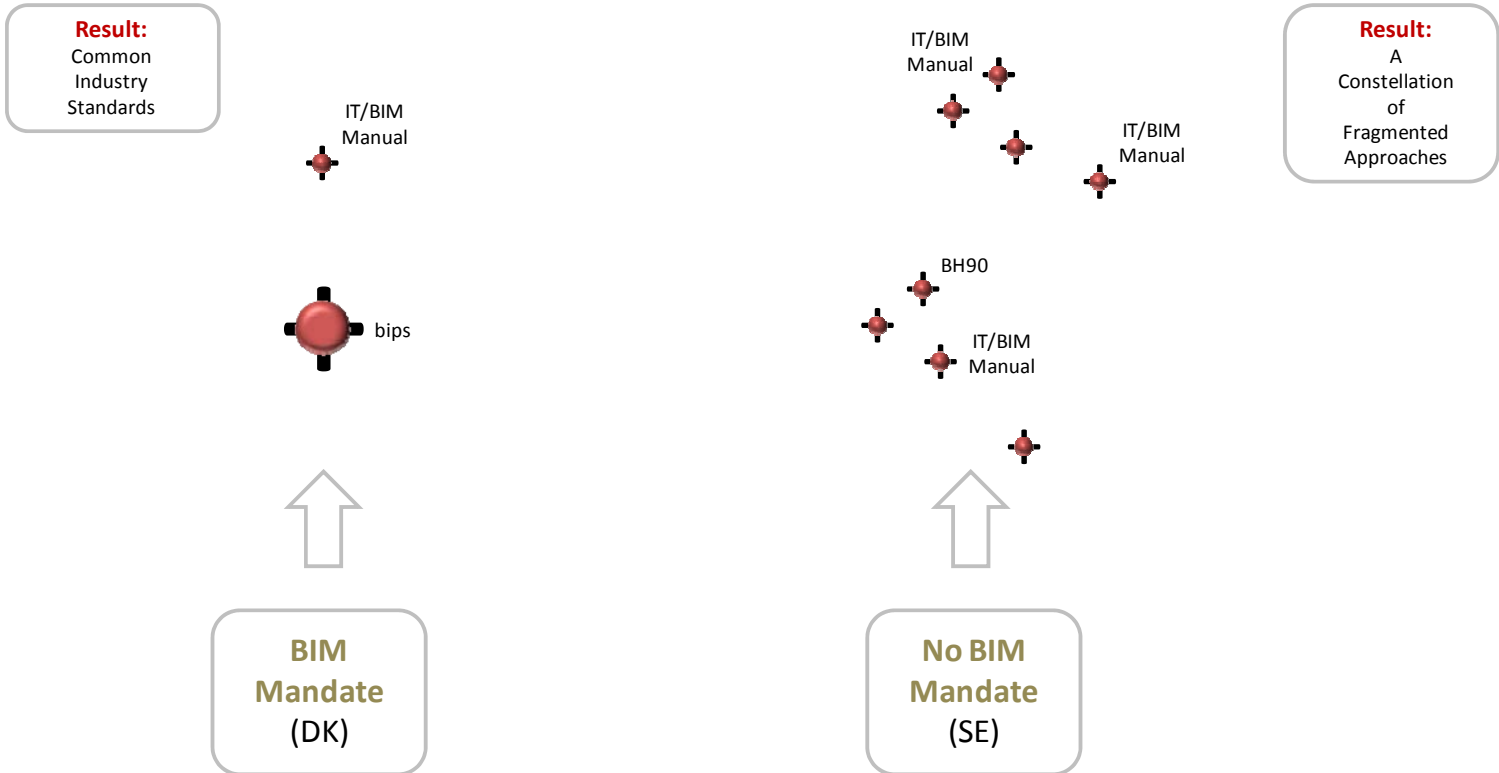
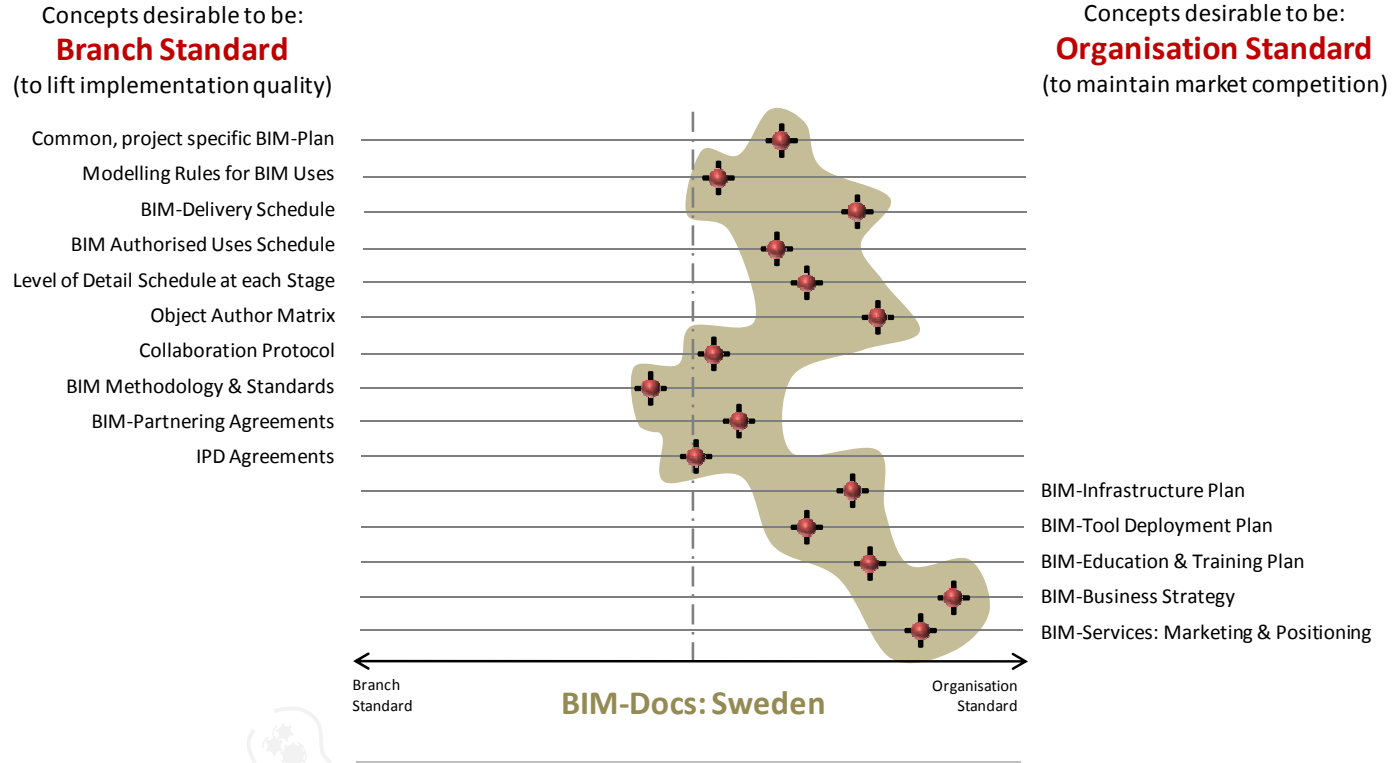


Figure 7: BIM-Platforms: DK & SE

BIM-Docs: Sweden – A Repositioning Proposition



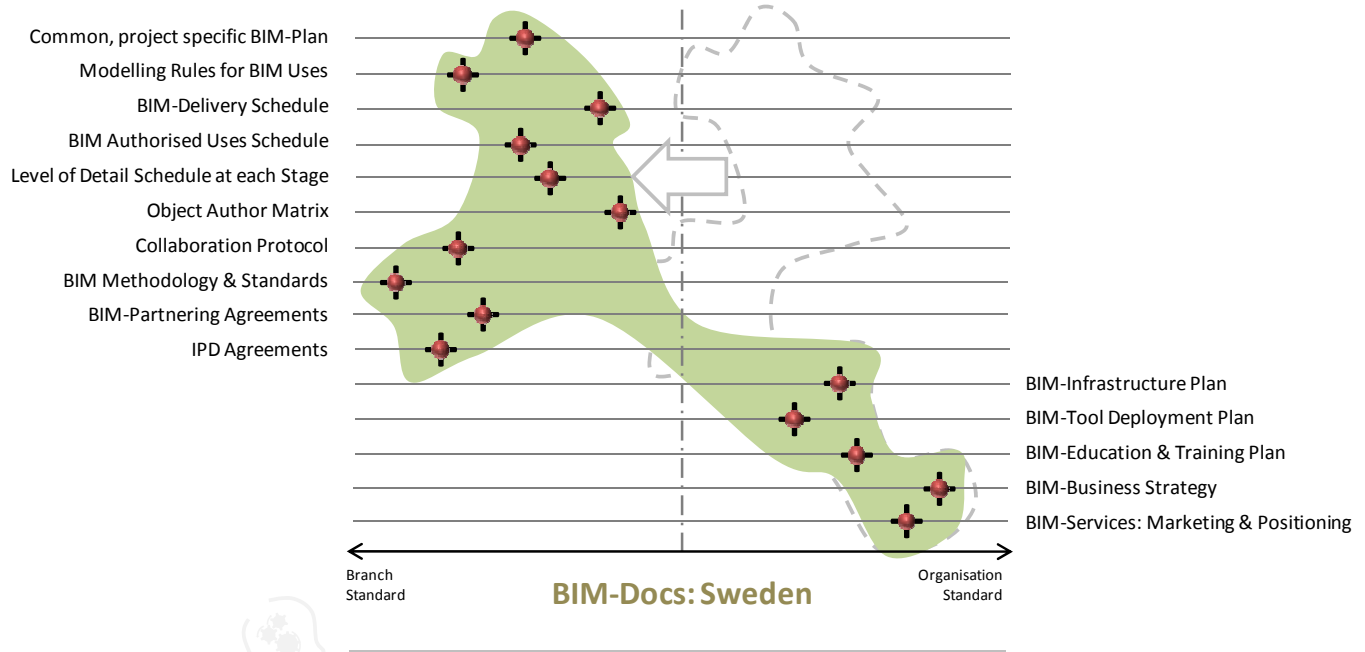
BIM-Docs: Sweden – Existing Positioning v1.0 (Hooper, 2011)

Figure 8: BIM-Docs: Sweden – Existing Positioning

BIM-Docs: Sweden – A Repositioning Proposition

Concepts desirable to be:
Branch Standard
 (to lift implementation quality)

Concepts desirable to be:
Organisation Standard
 (to maintain market competition)



BIM-Docs: Sweden – Desirable Positioning v1.0 (Hooper, 2011)

Figure 9: BIM-Docs: Sweden – Desirable Positioning

Findings / Conclusions / Recommendations

- ✦ If one looks at **other nations**, on the one hand one has a **government mandate** and on the other a state driven demand for BIM together with **state driven national standards**.
- ✦ In **Sweden development and implementation of BIM** has been deliberately **left to the AEC organizations**.
- ✦ **Challenges exists** in aligning or harmonizing DK / SE guidelines as they have **emerged from different drivers & initiatives**:
 - ✦ **BIM implementation & documentation in SE is largely market driven and the result of private initiatives. National guidelines are not specifically BIM orientated & don't have a broad audience.**
 - ✦ **DK guidelines are centrally driven and the result of public initiatives, have a broad audience, have the capacity to form the basis for BIM implementation.**
- ✦ There are a number of key BIM supporting concepts emerging elsewhere that are hidden / missing from both SE & DK models.
- ✦ If one is to harmonize DK / SE working methodologies, **one must look further** than bips & BH90 as **BH90 appears not to represent** or reflect practice BIM adoption in Sweden.
- ✦ There is a **tendency** or sector culture to **optimize at individual / organizational level only**, not the entire process.
- ✦ In Sweden there is a need to:
 - ✦ **identify and shift** those BIM supporting concepts, (hidden in organization's BIM documents) **to Branch Standards**,
 - ✦ define which BIM supporting concepts should be **contract**,
 - ✦ identify BIM services market competition drivers.
- ✦ **Architects role in Sweden** - architects must seize the opportunity to lead and raise their game; win back lost ground with BIM-leadership.
- ✦ **Education**: lack of BIM-training, leadership skills.
- ✦ **National BIM strategy** needs to be better documented & promoted.
- ✦ **Comprehensive, multi-audience set of guideline** documents to enable teams to learn, work better together, make strategic project-based decisions.
- ✦ **Government mandate** required to strengthen legitimacy to the Swedish BIM-drive.

References

- ✦ AEC UK (2010), *AEC (UK) BIM Standard for Autodesk Revit – Version 1.0*, London.
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